The Green Thumb

Spring/Summer 1987

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Number One

The Cover

Pawnee Buttes
Carolyn Crawford

Cut-back in Issues of *The Green Thumb*

Because of budget constraints at Denver Botanic Gardens, there will be only two issues of *The Green Thumb* published in 1987.

—*Editor.*

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Re-creating the Prairies:

THE LAURA SMITH PORTER PLAINS GARDEN AT DENVER BOTANIC GARDENS

by Richard Brune

Only 125 years ago, the Great Plains of eastern Colorado teemed with bison and other wildlife. A rich carpet of grasses and wildflowers covered the land. Today very little of eastern Colorado exists in that presettlement condition. Agriculture, ranching, and urban development have brought many prairie plant communities and their fauna to the brink of extinction.

The Laura Smith Porter Plains Garden at Denver Botanic Gardens re-creates some of the pristine presettlement prairies of Colorado. Funds for the garden were provided by Ruth Porter Waring in memory of her mother, Laura Smith Porter, who crossed the eastern prairies in a covered wagon in 1860. She saw Colorado's varied prairies in their virgin condition.

The flora of Colorado's Great Plains was exceptionally diverse when Laura Smith arrived. This diversity was due in part to Colorado's mid-continent location. For the past million years, alternate periods of climatic warming and cooling brought about great migrations of plants over the eastern plains. During cool periods, northern species such as needle-and-thread *(Stipa comata)* and western wheatgrass *(Agropyron smithii)* advanced southward. Warming periods produced northward advances of southern species such as blue grama *(Bouteloua gracilis)* and buffalo grass *(Buchloe dactyloides).*

With each advance of northern species during a cooling climate, southern species retreated southward except for

Indian grass, *Sorghastrum nutans,* a dominant grass of mesic tallgrass prairies

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Richard Brune, a chemist by profession but an amateur naturalist, has contributed untold hours researching for and re-creating the prairie plant communities for the Plains Garden at Denver Botanic Gardens.

those occupying a warmer, drier niche, such as a south facing slope. Similarly, each warming period produced a retreat of cool-season plants. Some of these also remained behind in cooler habitats—north-facing slopes or other areas with more available water.

The result of these pulsations in climate was a vast mingling of cool and warm season plants on the eastern plains. Today different groupings of plants, which are partly a result of these climatic fluctuations, are referred to as plant associations or plant communities. On the eastern plains we call them prairies.

These prairies seen by the early settlers evolved in about 10,000 years—the time since the last ice age. Plowing of the dust bowl years, overgrazing, and development have nearly eliminated many types of Colorado prairie. Estimates of the time needed for a prairie to regenerate vary from 50 years to hundreds or even thousands of years. To reestablish a prairie naturally may, indeed, require the thousands of years needed for its original establishment.

The Plains Garden

Ever optimistic, Denver Botanic Gardens is attempting to re-create fifteen different prairies in much less time. Each of the prairies at the Gardens will be shown in as pristine condition as possible. All the species are planted in their natural densities. For example, if copper mallow *(Sphaeralcea coccinea)* grows at an average density of one per square meter in the Blue Grama Shortgrass Prairie, that is the density planted. If a plant species grows naturally in groups, it will be planted in groups instead of randomly. Attention is also given to exposures and soil types where possible. With one exception—and ignoring a few introduced weeds—the Plains Garden contains only plants that are Colorado natives.

Much of our information on prairie plants and plant communities is from the work of many early prairie researchers such as F. W. Albertson, Ft. Hays State College, Kansas; H. C. Hanson, Catholic University of America, Washington, D.C.; F. Ramaley, University of Colorado; H. L. Shantz, U.S. Department of Agriculture; and J. E. Weaver, University of Nebraska. Additional data came from the Soil Conservation Service, the U.S. Forest Service and the Colorado Natural Areas Program.

The species and densities of the plants of the early prairies can be partially determined from the research of plant ecologists. In addition, Gardens staff members have visited many prairie types to determine how the re-created prairie should appear. To stand in the middle of a pristine prairie, with grasses and wild flowers extending to the horizon, is to realize we are limited in re-creating one intrinsic element of the prairie—the spaciousness.

The most intensive effort yet in the Plains Garden was made in 1986 with the addition of 87 new species of wildflowers totalling more than 2000 plants. Also, 8500 grass plants, including five new species, were added. About 2000 hours were spent on weed control alone. With all of this effort, we anticipate that 1987 will be a good year for wildflowers in the Plains Garden.

The following are some of the prairies being re-created in the Plains Garden at Denver Botanic Gardens along with a brief description of plants that will be of interest in 1987:

The Sandhills

Located in northeastern Colorado, the sandhills region is testimony that the area has one of the highest average wind velocities in the continental United States. Most of the sandhills are downwind (southeast) of the South Platte River. The sand, originating in the mountains, was carried to northeastern Colorado by the South Platte River and its tributaries. There it has been blown into dunes by the wind.

The sandhills region contains midgrass and tallgrass prairies in addition to loose sand and blowout communities. The plants, however, are generally different from midgrass and tallgrass prairies on heavier soils.

In Colorado, the sandhills prairies are among those most vulnerable to extinction. Loose sand is easily blown by the wind when disturbed—burying some plants and exposing others. Many rhizomatous sand-binding plants are easily uprooted by grazing. Conversion to center-pivot irrigation for agriculture is another threat. Sandhill prairies in pristine condition are nearly impossible to find.

Six kinds of sandhill plant associations are represented in the Plains Garden. Two of these, Sandsage/Sand Bluestem Prairie (*Artemisia filifolia/Andropogon hallii* Prairie) and Sand Bluestem-Prairie Sandreed Sand Prairie (*Andropogon hallii-Calamovilfa longifolia* Sand Prairie) are endangered globally and vulnerable to extirpation in Colorado.

In April and May in the sandhills at Denver Botanic Gardens hundreds of spiderworts *(Tradescantia occidentalis)* with their three-petaled blue flowers will begin blooming. Last year they bloomed every morning until August.

Painted milkvetch *(Astragalus ceramicus)* blooms about the same time. The small white flowers of this pea give no hint of the 1- to 2-inch long, inflated, red or purple mottled pods that will appear in June.

Penstemons should be prominent during May and June. *Penstemon albidus, P. angustifolius,* and *P. secundiflorus* are all planted in the sandhills. Although it is not known from Colorado, *Penstemon haydenii,* the rare and endangered blowout penstemon of the Nebraska sandhills is also planted in the Plains Garden.

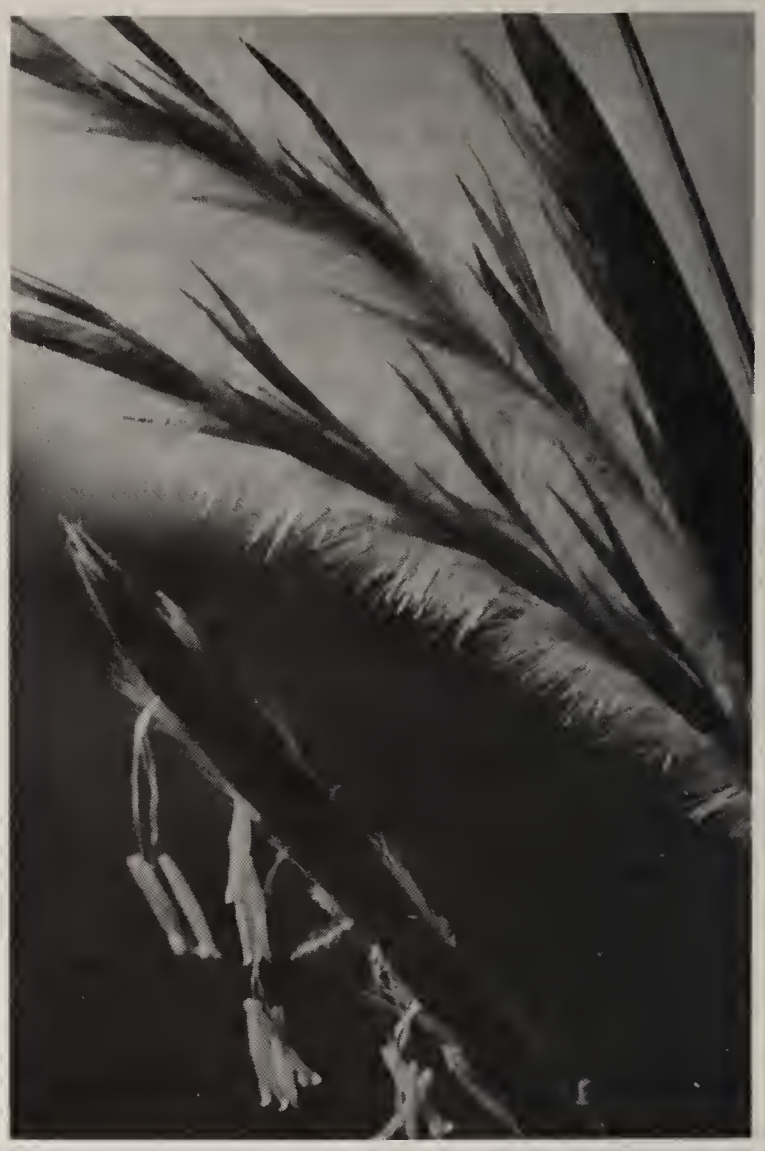
Two of the earliest flowering grasses in the Plains Garden, Indian ricegrass *(Oryzopsis hymenoides)* and needle-and-thread, grow in the sandhills. Indian ricegrass with its slender branches and open panicles is in full bloom by the end of May. Besides being ornamental, its relatively large seeds have long been used as a food source. The 6-inch awns of needle-and-thread distinguish this grass from all others in the Plains Garden. These long awns are attached to the sharp "needle" which contains the seed.

Needle-and-thread is a grass which actively plants its seed. After the seeds fall, the long awns twist and turn with changes in humidity. The twisting motion serves to drill the seed into the ground. Last year on a day in late June, this feature provided much amusement for the gardeners as well as several visitors who wondered what we were so intently watching on our hands and knees. This is a very striking grass when backlit in the early morning sun.

A pretty annual in the sandhills in late spring is rusty or low lupine *(Lupinus pusillus).* Its blue and white flowers should appear in May and June from seeds planted in October.

During July and August, white-flowered annual heliotrope *(Heliotropium convolvulaceum)* blooms in the loose sand and blowout communities. Blowouts, often considered undesirable because they indicate active soil erosion, are natural features of the sandhills landscape when they occur in small numbers. Many rare and unusual plants occur only in and around blowouts where competition from other plants is minimal. With their flowing lines and smooth

Inflated pods of painted milkvetch, *Astragalus ceramicus*



Sand bluestem, *Andropogon hallii,* a prominent grass of sandhill prairies

Purple prairie-clover, *Dalea purpurea,* readily eliminated by overgrazing

Two-inch wide white flowers of white-stemmed evening primrose, *Oenothera nuttallii*

Well-preserved sandhill prairie on a private ranch in Weld County

sand, they can be quite attractive when carpeted with heliotrope and surrounded by blowout grass *(Redfieldia flexuosa)* and silky prairie clover *(Dalea villosa)*.

In late afternoon and evenings in summer our sandhills are abloom with evening star *(Mentzelia nuda)*. It is always surprising to find the delicate yellowish white flowers of evening star in full bloom, when only 20 minutes earlier they were all tightly closed.

White-stemmed evening primrose *(Oenothera nuttallii)* and plains yellow primrose *(Calylophus serrulata)* of the evening primrose family bloom here from late spring into autumn.

In the sandhills, as in much of the Plains Garden, the tall grasses reach their peak in autumn. Sand bluestem is particularly attractive with pastel stems of alternating blue and pink; the much shorter ring or sandhill muhly *(Muhlenbergia pungens)* will give the sandhills a purplish-red tint in autumn when it is established in quantity. Both sand bluestem and ring muhly can lend a special touch to dried arrangements.

Midgrass Prairies

Midgrass prairies in Colorado are dominated by grasses less than 3 feet tall. They occur on gravelly or rocky soils with good moisture penetration or on soils where additional moisture collects from runoff.

Four examples of this prairie type are planted in the Plains Garden. Needle-and-thread Mixed Prairie was once common on upland sites throughout northeastern Colorado. Today it is known only from scattered remnants, mostly along the Front Range. Little Bluestem *(Schizachyrium scoparium)* Loess Prairie is known only from Kit Carson and Yuma Counties. Both of these prairies are threatened with extirpation. Little Bluestem Mixed Prairie of rocky soils and Western Wheatgrass Mixed Prairie of heavy soils are also represented in the Plains Garden.

In April and May, our midgrass prairies will have many spiderworts in bloom, just as in our sandhills.

With almost 100 plants of Colorado loco *(Oxytropis lambertii)* planted in 1986, the spikes of its purple-red flowers may make quite a show this spring. One of the most attractive of prairie wildflowers, it is widely known to be toxic to horses. Two other legumes, field milkvetch *(Astragalus agrestis)* and American vetch *(Vicia americana)*, should also bloom this spring. American vetch rapidly disappears with grazing on native prairies.

Two yellow spring-blooming composites, *Senecio fendleri* and *Senecio longilobus,* will contrast with the blue of our wild blue flax *(Linum lewisii)*. Cutleaf ironplant *(Haplopappus spinulosus)* is really more attractive than the name im-

plies. During 1986, our 12-inch tall, somewhat bushy plants were covered with yellow flowers until November.

The blue flowers of *Penstemon angustifolius* and *P. secundiflorus* appear during May and June on lighter soils of the midgrass prairie.

Purple prairie-clover *(Dalea purpurea)* blooms all summer in the Plains Garden. Beginning at the base of the 2-inch long, cylindrical spike, the purple flowers open in a ring around it. As new flowers open and old ones fade, the ring of flowers advances up the spike. This plant is a great favorite with bees in the Plains Garden. It appears to be one of our toughest prairie wildflowers surviving being planted with inadequate roots and missed waterings. Unfortunately, this plant as well as white prairie-clover *(Dalea candida)* are rapidly eliminated when grazed.

Prairie coneflower *(Ratibida columnifera)* and its purple-flowered form, mexican hat *(R.C. pulcherrima),* are commonly grown in gardens. Both are Colorado natives that bloom until the end of July.

Blooming throughout the summer in our midgrass prairie is blanket flower *(Gaillardia aristata)* with yellow to purple ray flowers. It is another Colorado native often planted in gardens.

Blazing star *(Liatris punctata)* is sometimes seen as a harbinger of Autumn. Pink- to purple-flowered spikes appear in early August. Spikes of feathery seeds, attractive in their own right, follow, often taking on a bright silvery appearance. This wildflower is readily eaten by livestock when young and decreases with grazing.

Two of the most ornamental grasses in the Plains Garden that bloom in late summer are little bluestem and big bluestem.

Little bluestem has foliage ranging from reddish purple to brick red topped with a contrasting white, curving inflorescence. Its stiffly erect 2-foot stalks are often seen protruding through the snow when many other grasses are flattened. This is one of the choicest grasses for dried arrangements and should be used much more in landscaping.

Big bluestem or turkeyfoot *(Andropogon gerardii)*, one of the dominant grasses of tallgrass prairies, also occurs in midgrass prairies. The 4- to 6-foot tall plants vary in color from blue-green to purple to red in an indescribable number of hues. The name turkeyfoot refers to the 2- to 7-branched inflorescence resembling a turkey's foot.

Shortgrass Prairies

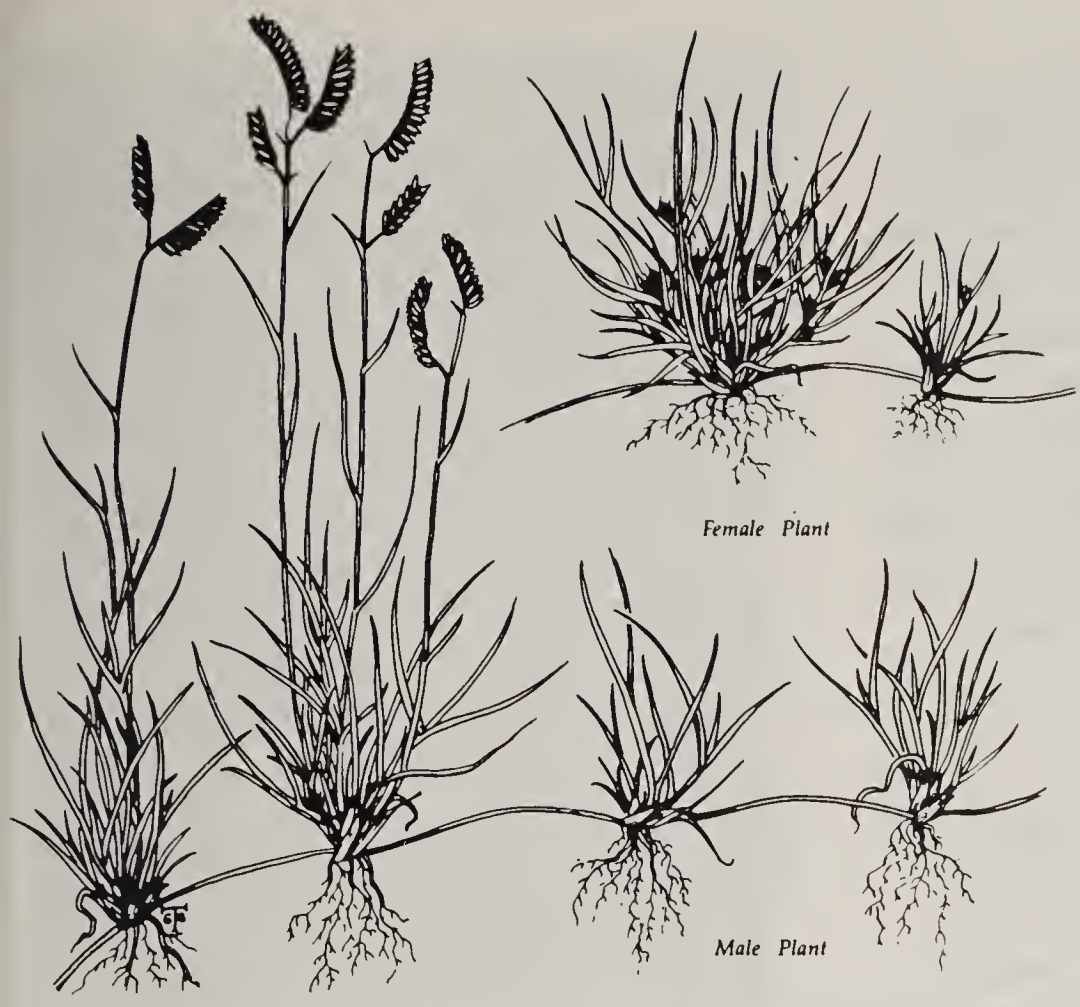
Shortgrass prairies occur in eastern Colorado on soils where the available moisture is usually consumed by mid-July. Most plants become dormant at this time. Following a rain some are able to quickly resume growth and even produce seed.

Considerable debate continues concerning the existence of the shortgrass prairie as a climax community. Some early explorers reported midgrass prairies where, today, there appear to be shortgrass prairies. Others have reported that parts of the prairie have always been shortgrass. Some areas with a shortgrass appearance may, upon close examination, actually be midgrass prairies with the grasses much reduced by grazing.

Four types of shortgrass prairie are being planted in the Plains Garden. These usually occur on heavier soils than the midgrass prairies, and all are dominated by grasses less than a foot high. A few midgrasses are also present.

The short grass probably most familiar to everyone is buffalo grass, often used for low water requirement lawns. Buffalo grass is dioecious; that is, it has separate male and female plants. This wasn't recognized initially, and for some years after its discovery the male and female plants were considered different species.

Blue grama is the most common grass of the shortgrass prairie. It has also been called buffalo grass in the past. This is reported to be the most drought-tolerant of our native grasses and, like buffalo



Buffalo grass, *Buchloe dactyloides*

Blue grama, *Bouteloua gracilis*

grass, is used for low water requirement lawns.

Spring-blooming flowers in our shortgrass prairies include the cacti. Hedgehog cactus *(Echinocereus viridiflorus)* uses the lime scent of its greenish flowers to attract insects. Similar in habit is the pincushion cactus *(Coryphantha vivipara)* that has bright pink blossoms to attract insects. Other cacti include the yellow- to pink-flowered prickly pears *(Opuntia fragilis, O. humifusa,* and *O. polyacantha).*

Groundplum or buffalo pea *(Astragalus crassicarpus)* is a spring-flowering legume once so abundant it tinted the prairie pink. By mid-June, ours are covered with tasty, succulent, purple and green "plums." On the eastern plains, this nutritious pea is quickly eliminated by grazing.

Two showy annuals bloom early in the shortgrass prairie. One is the prairie evening primrose *(Oenothera albicaulis)* which has 2-inch wide white flowers. The other, the tansy aster or tahoka daisy *(Machaeranthera tanacetifolia)* with blue to purple ray flowers, is cultivated as an ornamental. With supplemental watering, both bloomed until late September in 1986—long after they ceased to bloom on the eastern plains.

Copper mallow or cowboy's delight is probably the most drought-tolerant wildflower on the eastern plains and also in our Plains Garden. This was one of the few plants to increase in numbers during the drought of the 1930s. The common names describe its appearance and utility as a forage plant. We hope to plant many more of this species in the Garden.

Two perennial members of the evening primrose family are planted in the shortgrass prairies. Scarlet gaura *(Gaura coccinea)* has small white flowers which fade to pink or red. Combleaf evening primrose *(Oenothera coronopifolia)* has white flowers. Both spread by rhizomes to form large colonies.

Bison uprooted the prairie sod to cover themselves with dust and mud to fend off insects and also as a displacement activity during the rutting season. Low, wet areas were particularly favored. The resulting "buffalo wallows" that formed support a somewhat distinctive flora of their own. Planted in the wetlands around the Gates Pond are three of these

species: Spotted evening primrose *(Oenothera canescens)* has attractive pink flowers dotted or streaked with red. Water clover *(Marsilea vestita)* is a fern that looks totally unlike a fern. The leaves are four bladed and resemble clover or oxalis leaves. The sori are contained in hard sporocarps attached to the rhizomes. Fog fruit *(Lippia cuneifolia)* has inch-long cylindrical spikes of small white flowers. Does anyone know the origin of this unusual common name?

Tallgrass Prairies

Many people are surprised to learn that tallgrass prairies, usually associated with the midwest, exist in Colorado.

The two tallgrass prairies being developed in the Plains Garden are Big Bluestem-Little Bluestem Xeric Tallgrass Prairie and Big Bluestem-Indian Grass *(Sorghastrum nutans)* Mesic Tallgrass Prairie. Both are nearly extirpated in Colorado. The mesic tallgrass prairie is threatened throughout its range.

The xeric tallgrass prairie is dominated by big bluestem and little bluestem. The openness of this prairie allows the growth of many wildflowers throughout the growing season. Short grasses such as blue grama and side-oats grama *(Bouteloua curtipendula)* are important understory plants.

The mesic tallgrass prairie is also dominated by big bluestem but includes co-dominants such as Indian grass, switch grass *(Panicum virgatum),* and little bluestem. The density of these grasses is greater than in the xeric tallgrass prairie, so short grasses often do not occur. The shorter wildflowers bloom early in the season before they are overtopped by the grasses. Taller wildflowers bloom progressively later in the season.

The tallgrass prairies at the Gardens are being redeveloped. The initial plants were effectively choked out by weeds—notably mallow *(Malva neglecta)* and blue mustard *(Chorispora tenella).* After we controlled the weeds and reseeded, the tallgrasses reached heights of 4 to 6 feet in 1986. Unfortunately, nearly all of the grass is switch grass. Other grasses either did not germinate well or were choked out by switch grass.

In 1987 we will remove the excess switch grass and plant individual plants of the other grasses and wildflowers in their proper densities. The process of planting individual plants, rather than broadcasting seed, worked well for grasses and wildflowers in 1986. Although this method is time consuming, the desired densities are immediately obtainable. The plants also get a better start without competition from broadcast sown grasses. In areas previously seeded, places cleared for new plants were immediately invaded by buffalo grass and western wheatgrass.

Most of our prairie wildflowers showed great tolerance for the intense competition. They survived remarkably well buried in the grasses—as they might in a

Mesic tallgrass prairie near Boulder, Colorado

healthy native prairie. Plants grown with less competition, however, were unquestionably larger.

The plants described here are those that we are reasonably certain will bloom in 1987. Many others were also planted and, hopefully, many will bloom.

Most perennial prairie plants put their first years of growth into developing their underground reserves. This occurs before any energy is expended for flowering. For example, bush morning glory *(Ipomoea leptophylla)* apparently requires three years to bloom from seed. Prairie-turnip *(Psoralea esculenta)* needs about five years to bloom. Tallgrasses grow 6 to 10 inches tall the first year from seed only to leap to 6 feet tall the second year.

Some of the plants in the Plains Garden have not been cultivated before. Many of these will probably grow well; others will fail. Some we will probably regret having ever planted!

As the Plains Garden matures, we hope visitors to Denver Botanic Gardens will learn and understand more about the beauty and value of the eastern prairies. For the observant traveler, the Colorado prairies offer much more than a boring drive to the distant mountains. A visitor to the prairies today can still find remnants of the former splendor of Colorado's Great Plains.

High Plains escarpment in Pawnee National Grasslands

Where to See Native Prairies

Examples of the prairies re-created in the Plains Garden at Denver Botanic Gardens can still be found in eastern Colorado, though rarely in pristine condition. They range in size from remnants of a few acres to tracts of thousands of acres. Some of the best examples are privately owned and inaccessible to the public. Described here are the locations of some publicly accessible prairies and prairie features in eastern Colorado. Because of the threatened status of many of these prairies, plant collecting is forbidden.

Sandhill Prairies

The sandhills region extends from near Keenesburg to around Sedgwick on either side of Interstate 76. The beginning of the sandhills is marked by an abrupt change from agricultural use to ranching. Most of this area is private land but many sandhills plants inhabit the roadsides.

The Tamarack Ranch Wildlife Area northeast of Sterling is public land and supports a fair to good condition sand prairie. Various management techniques, including burning and herbicides, are being used to improve the quality of the prairie. Grazing is no longer permitted. The effects of prescribed burning may be observed here. In addition, the greater prairie chicken has been reintroduced to the area.

Part of the Wildlife Area was designated a Colorado Natural Area in 1986 (470 acres in T10N R48W S ½ Sect. 20). This area may be reached from the highway rest stop on I-76 about 1.75 miles east of the Crook exit. From the rest stop, hike 0.5 miles south and 1.5 miles east to the Colorado Natural Area. Much of the ridge to the south is similar to the Natural Area.

Tamarack Ranch also contains a good condition stand of Plains Cottonwood-Plains Willow/Sandbar Willow Riparian Woodland (*Populus deltoides* ssp. *monolifera* – *Salix amygdaloides*/*Salix exigua*) that has been given Colorado Natural Area status. To reach this site, take Colo. 55 north from the Crook exit off I-76. After crossing the first bridge over the South Platte River, turn west (left) onto a gravel road and drive about 8 miles to this natural area. Much of the riparian vegetation along the river here is similar to that in the designated site.

Tallgrass Prairies

Few people who commute between Denver and Boulder realize they pass some of the last remnants of tallgrass prairie in Colorado. These prairies are managed by City of Boulder Open Space and Colorado Natural Areas Program.

A Big Bluestem-Indian Grass Mesic Tallgrass Prairie borders the north side of U.S. 36 about 0.25 mile east of the Cherryvale Road overpass. This Prairie is reached by going south on Cherryvale Road from Boulder Road to the Cherryvale Road overpass of U.S. 36. Turn east on the northside of the overpass and park at the bottom of the hill. Walk about 100 yards southeast adjacent to the highway to the 17-acre prairie.

Across the highway to the south is Davidson Mesa—the site of a 99-acre Big Bluestem-Little Bluestem Xeric Tallgrass Prairie accessible from Marshall Road (Colo. 170), which may be reached by continuing south on Cherryvale Road or from Colo. 93 south of Boulder. Access is by a marked easement across private land on the north side of Marshall Road about 0.1 mile west of 66th Street. Large groups should contact Open Space personnel before entering the site. (Ref. 1)

West of Colo. 93 south of Boulder are additional areas of mesic and xeric prairies. Take Thomas Lane to its western end; the prairies are to the south with upper slopes covered by xeric prairies and lower slopes by mesic prairies. Others in

the Boulder area are described in reference 2.

Mesa de Maya, 65 miles east of Trinidad, supports areas of xeric tallgrass prairie on top of the mesa and mixed prairie on its slopes. Mesquite and bear grass communities are found here also. This area is all private land. Information on access, field trips, and seminars on the archaeology, botany, geology, history and wildlife is available from Mesa de Maya Field Seminars. (Ref. 3)

Tallgrass prairie sod, when available, was the choice material for building sod houses—especially when it contained the strong rhizomes of prairie cordgrass (*Spartina pectinata*). The Wheatridge sod house (Ref. 4), located on the Clear Creek floodplain, is built from sod that contains much prairie cordgrass. Built between 1869 and 1889, it indicates that this area once supported large, if not extensive, stands of tallgrass prairie. Until recently, prairie gentians (*Eustoma grandiflora*), an indicator plant for mesic tallgrass prairies, grew in the area.

Midgrass Prairies

Bonny State Recreation Area north of Burlington is the only existing site for Little Bluestem Loess Prairie in Colorado. This prairie occurs in three fragments on the north side of Bonny Reservoir along the main access road.

Site 1 begins at the Foster Grove campground turnoff and runs east 0.25 mile on the north side of the road. (T5S R43W portions SE ¼ Sect. 18).

Site 2 is on both sides of the road at the summit of a small hill 1.0 mile east of the campground turnoff. (portions SE ¼ Sect. 19)

Site 3 is on both sides of the road at the north end of Bonny Dam landing strip.

The Plains Conservation Center (Ref. 5) in Aurora is a mosaic of areas of Needle-and-Thread Mixed Prairie and Western Wheatgrass Mixed Prairie. The best site of Needle-and-Thread Mixed Prairie is about 0.75 mile north of Hampden Avenue and 0.75 mile west of East Tollgate Creek (NW ¼ Sect. 35). The Center is open to the public on Saturdays from 1 to 3 pm and for group tours and other activities by appointment. Various educational programs related to our prairie heritage are conducted throughout the year.

Rabbit Mountain northeast of Lyons has stands of Little Bluestem Mixed Prairie on outcroppings of Dakota sandstone. Owned and managed by Boulder County Open Space, access to the area is via North 53rd Street about 1 mile east of the junction of U.S. 36 and Colo. 66. Follow North 53rd Street north 2.7 miles to a marked access on the east side of the road. An area of Mixed Prairie is about 0.5 mile east of the trailhead on a gentle west facing slope almost directly above the irrigation tunnel.

Other mixed prairies occur on the uplands and breaks in Pawnee National Grasslands.

Shortgrass Prairies

The Pawnee National Grasslands are a vast checkerboard of public and private lands northeast and northwest of Briggsdale about midway between Ft. Collins and Sterling off Colo. 14.

The campground and picnic area just north of Briggsdale has a map and information describing the origin of the National Grassland. Although the campground is planted mostly in exotic crested wheat, the ridge 0.2 miles north of the campground has many prairie wildflowers. Crow Creek along the south and west sides of the campground has some plants of prairie wetlands.

The popular area known as Pawnee Buttes is northeast of Briggsdale at the junction of the Colorado Piedmont and the High Plains. For access, drive east from Briggsdale on Colo. 14 about 9 miles to Rd 95 and turn north. In about 2.7 miles there is a rock outcrop on the west side (private land) that is a fossil stream channel. Thirty million years ago this stream carried material from the eroding Rocky Mountains across the Great

Plains. Similar fossil stream channels exist east of Keota and elsewhere.

Continue north to Rd 96 and turn east. After 3.8 miles, this road makes a short jog around the south side of an old buffalo wallow. Turn north on Rd 103 to the near ghost town of Keota. From Keota, take Rd 105 north from the east side of town. After 2.5 miles turn east on Rd 104. Follow Rd 104 for 3 miles to Rd 111; then go north on Rd 111 for 4 miles to Rd 112.

The road to the scenic overlook of Pawnee Buttes is well marked at the junction of Rds 111 and 112. This area has Needle-and-Thread and Little Bluestem Mixed Prairies on the slopes around the escarpment. The gently rolling prairies extending to the horizons are mainly Blue Grama-Buffalo Grass Shortgrass Prairies.

A scarp woodland west of Pawnee Buttes supports a relict stand of limber pine and ponderosa pine. Located on rocky, northfacing slopes, these woodlands are believed to be remnants of a forest which extended eastward from the mountains during the last ice age.

The woodland may be reached by driving west on Rd 112 for about 2 miles to Rd 107. About 1 mile north on Rd 107 a dirt road leads to the east near the top of the hill. This road may be driven or hiked for about 1 mile to the woodland on the northfacing escarpment.

As you observe these native remnants of the vast Great Plains, remember their fragility and the importance of conserving them for future generations.

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   Chris Wilson 444-0436
   Dick Antonio 494-2194
2. Baker, W.L. and S.M. Galatowitsch. 1985. *The Boulder Tallgrass Prairies.* Boulder County Nature Association.
3. Mesa de Maya Trail Seminars
   P.O. Box 68
   Branson, CO 81027
4. Wheatridge Historical Park
   4610 Robb Street
   Wheatridge, CO 80033
   Open 2nd and 4th Saturdays of month, 12-4 pm.
5. Plains Conservation Center
   21901 E. Hampden Ave.
   Aurora, CO 80013
   (303) 693-3621

Suggested Reading

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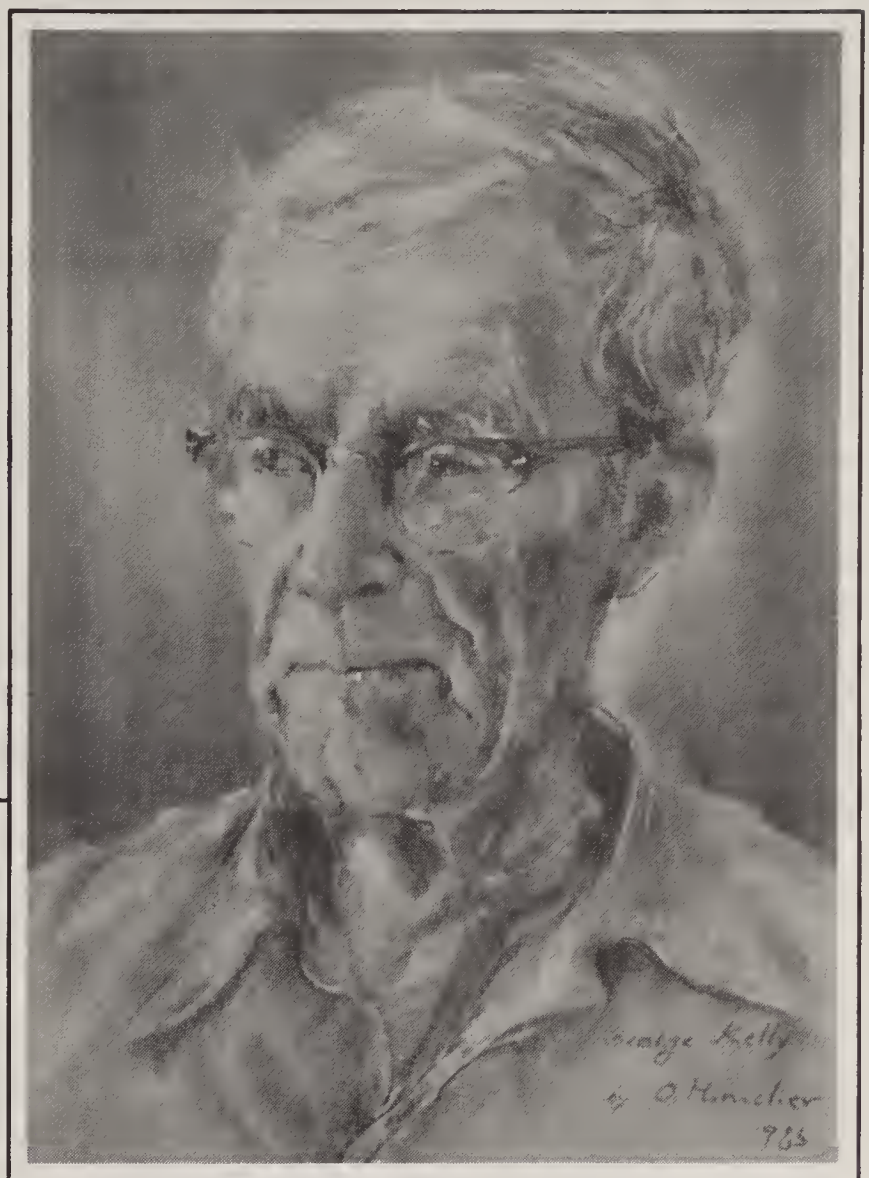
George W. Kelly: A Year of Awards

Our congratulations to Mr. Kelly who also was honored recently by the Association of American Nurserymen; by the City of Cortez, Colorado, Centennial Commission; and by the Colorado Chapter of the American Society of Landscape Architects.



From a portrait of Mr. Kelly by Olga Miniclier

Denver Botanic Gardens

Resolution of Appreciation

George W. Kelly

Visionary plant lover and master plantsman, conservationist, outdoorsman, friend to all who garden where "Rocky Mountain Horticulture is Different," we salute you. You were an essential member of the small group who worked diligently for so many years to bring a botanic garden to fruition in Denver, and you were one of the six Founders. As a Charter Trustee and Acting Director, you helped guide the early progress through a very difficult period. Our grateful thanks to you for planting the roots of our present-day Denver Botanic Gardens, now acclaimed internationally for its excellence.

Your portrait, now hanging in a prominent position in the Helen Fowler Library, reminds us daily of you and your contributions. This resolution is an expression of wholehearted appreciation to you, George Kelly, from the Trustees and Members of Denver Botanic Gardens.

Edward P. Connors, President
Board of Trustees

Moras L. Shubert, Secretary

DENVER BOTANIC GARDENS INC. COLORADO

at Denver, Colorado, this twenty-sixth day of September, nineteen hundred and eighty-six

Denver Grows Up: Ideas for Shade Gardens

by Andrew Pierce

Since time immemorial when man started to construct buildings, he created shade; and then, superimposed on this, he planted trees and our depths of shade became even greater. Many residents of older Denver have considerable amounts of shady garden created not only by themselves but by nearby neighbors as well. Often such areas are neglected; but certain plants have been available for the avid gardener for a number of years to brighten the shade corner.

If no large trees are present, shade is generally confined to the narrow portion of the garden on the north side of buildings; but as soon as trees are added the useful shade area is extended. Man-made wooden structures such as pergolas, overhanging decks, and patios produce shade lines even farther into the garden and away from buildings. These taken together can provide restful and welcome relief from the hot summer sun.

Shade is difficult to classify; indeed, one's perception can change with the passing time of day, month or year. In considering the development of shade gardens, the following classification can be used.

Andrew Pierce, assistant director of Denver Botanic Gardens, is an experienced and knowledgeable horticulturist who teaches classes on flower gardening at DBG.

Dense shade
No sunlight reaches directly onto the plants except, perhaps, the tallest specimens. Not the best situation for color, but with the use of form, foliage (both color and shape), sculpture, rocks and water it can be made attractive.

Heavy shade
Plants receive two to three hours of sunlight a day. Lively colors are extended considerably here—often the situation with a north wall that receives one or two hours of both east and west sunlight a day for part of the year.

Partial shade
Sunlight may reach the plants four or five hours a day, and the range of useful plants increases dramatically. Some normally sun-loving plants may succeed but may not be as floriferous as in full sun.

Dappled shade
Typically found under lighter foliage trees such as honey locust, golden rain, birch and perhaps even the hackberry. Plants may receive four to five hours of sunshine; but other factors such as root competition and rainfall patterns influence plant survival.

Indirect and reflected light
Light, often in good values penetrates into the area. Most typically this is: a north side with no overshadowing trees

Western bleeding-heart

Red columbine

Dwarf columbine

in that direction but with the east and west sun angles blocked by higher shade plants or buildings; or reflected light where light colored buildings direct quantities of light into a shade area. Of course, if the buildings have a lot of glass, heat reflection may be so intense as to damage the plant material even though it is in the "shade."

Plant factors

In the open, sunny garden we tend to look at a plant primarily for its flowering capabilities whether intense and short-lived as early flowering forsythia shrubs and crab apple trees or the longer season splendor of tulips, daffodils, petunias and geraniums. In the shade garden other more subtle features take prominence.

Leaf shape

By putting a relatively long narrow leaf of a fern against a dark broad one of a hosta or plaintain lily a pleasing effect may be created. Feathery leaves of bleeding heart and columbine contrast well with the bolder leaves of bergenia and bloodroot. Every leaf has a special shape or texture that can create contrasting effects.

Leaf color

Where would we be without this valuable feature in the shade garden? Green comes in so many tones we often fail to use its potential. Greys and almost blues of hosta, dark green of ivy and variegations of several different plants are examples.

Form

Clumps of juniper may be monotonous in some areas of the garden; but given the right choice of variety and shape, they may be a very useful adjunct to the partial shade garden.

Ground covers

Even more than in the open garden, ground covers are needed to direct the eye into more than one elevation of plant material. Because of surrounding buildings and the varying angles of the sun, low light gardens tend to be smaller and ground covers can be influential in giving a garden personality.

Flowers

Flowers are not always the dominant feature in the shade garden. Splashes of color are very effective, and in some instances a mottled appearance is all that is required. The advocates of color will insist on large plantings of begonias and impatiens for their riotous hues, but shade gardens often demand fewer flowers. Subtle effects are important to make an area cool and refreshing.

Other design features

Careful use of ornamentation and physical features can extend the beauty of the shady location. The positioning of suitable rocks, sculpture, level changers such as railroad ties and low walls and the careful selection of material for path surfacing can be complementary to the overall design. With small areas careful thought must be given to any positioning of ornamentation. Rocks can be used individually for visual prominence, as a dry stream bed that may be a drainage channel as well, or to surround a small waterway. The latter with its cooling appearance and sound effect makes a pleasing addition to the shady nook.

Another important consideration for a shade garden is drainage. Obviously, with less sunlight there will be less evaporation from the soil; and if the shade garden is in a lower level, runoff from areas receiving higher precipitation, such as a nearby lawn area, will only confound the problem. Initially it may be necessary to build in a drainage system of 6-inch perforated pipe laid 12 inches below grade, covered with gravel or similar porous material to take excess moisture from the site. Often natural grades can be used to relieve the problem. Alternately it may be practical to use design features of railroad ties or small walls to raise levels, and then use a mixed stone path as your drainage system by using stepping stones among or even over large gravel. The red of brick to accent a shade garden may be incorporated into small walls, planters and pathways.

Cultural considerations

Generally shade plants tend to require an open, friable soil fairly high in organic matter that drains well but only moderately high in available nutrients. A typical mix could be 3 parts existing soil, 2 parts organic matter (peat, compost, leaves, etc.) and, if on a clay soil, ½ to 1 part course sand or fine gravel. For the woodland garden incorporate 3 to 4 inches of leaves into the top 4 to 6 inches of soil. Top with a mulch of leaves to help retain moisture in summer. The soil depth should be at least 10 inches after final settling. The level below the bed areas should drain so the water that percolates through the bed does not build up on a hard pan as this could kill the plant roots by depriving them of oxygen.

If a light fertilizer dressing (10-10-10) is given at bed preparation time with some additional bone meal when planting, little more fertilizer will be required over the first couple of seasons provided that root competition is not severe. Should the odd plant or group fail to flourish, a liquid feed may be all that is needed to boost it along.

Trees and large shrubs are lovely as backdrops for their cooling effect; but their roots often sap the moisture and nutrients from the very shade garden being created. Judicious root pruning can be done, but some plants, e.g. poplars, conifers, large maples and oaks, will deplete the soil of every bit of quality and nutrients over a number of years. Choose plants wisely, especially dominant trees. Quite often the problem may be caused by neighboring plantings.

As with the rest of the garden, the problem of when and how much to water must be considered. With the variables in a shade garden, moisture retention is difficult to assess. An area enclosed by non-ventilating buildings and solid wooden fences has a different microclimate from another without solid obstructions hindering air movement. Each garden will have different watering needs. To handle this variability, never tie the shade garden in with a lawn sprinkler system. Low systems of trickle irrigation and small bubblers permit watering on a random basis. A hose pipe with a nozzle breaker on the end may take more time to water, but it does allow for wetting the drier patches more. Also it gives the opportunity to remove the odd weed and dehead the occasional spent flower. When watering do it thoroughly to moisten the soil down to full bed depth. Even in the height

Dwarf crested iris

Nodding wake-robin

of summer, twice a week will be sufficient. Extra water conservation can be attained with mulches of wood chips or coarse peat spread over the surface 1 to 2 inches deep. Generally stone chippings as a mulch appear harsh in the shady area.

Plants for low light areas

There is a large selection of plants that can lend color to the shade garden in early spring before the deciduous trees get their foliage. Eastern woodland plants such as *Phlox divaricata, Iris cristata, Hepatica americana, Anemonella thalictroides* and *Trillium* species create mats of color just as the tulip trees, oaks and maples are leafing out. Other plants for the same location, that have more persistent and attractive foliage are *Asarum canadense, Arisaema triphyllum, Sanguinaria canandensis* and *Podophyllum peltatum.* Their flowers may not be spectacular but they tend to bloom early in the season. This woodland situation can be further enhanced by the use of snowdrops, aconites, some tulips and daffodils to extend the season of bloom into late spring.

Planting density

With the apparent lack of shade-loving plants that bloom for a long season, consider extending the value of the shade garden by using a variety of plants rather than a massing of any one species. The lists at the end of the section will give you some indication of plants to use. It will not necessarily tell you that bleeding heart usually flowers in late May and is one of the best plants for the shade garden, nor that creeping periwinkle is a great ground cover, sometimes to the extent that other perennials fail to grow through its mat. Such information will have to be gleaned from experience and from the Gardens' library where there is a good selection of useful books on shade gardening. Again one's choice and personality come into play, as no two people's expression of "what a shade garden is" are the same.

Shade areas are with us and their value should be appreciated rather than abhored. Many of the metropolitan housing estates look bare and their trees small for their first few years; but given time the same situation that persists in older Denver today will slowly become noticeable. Then the change from growing in the sun will be replaced by shade-loving plants. Shade is a marvelous adjunct to many gardens if used in an appropriate manner.

Plants for Shade Gardens

S — Shrub
A — Annuals
F — Foliage
W — Woodlander
B — Bulbs & Corms
G — Ground covers
E — Early bloom
T — Tall herbaceous perennials
L — Low herbaceous perennials

Code	*Botanical name*	*Common name*
S	*Acer ginnala*	Amur maple
T	*Aconitum napellus*	Garden monkshood
F	*Adiantum pedatum*	American maidenhair fern
T	*Anchusa azurea*	Bugloss
T	*Anemone hupehensis*	Japanese anemone
E, W	*Anemonella thalictroides*	Rue anemone
T	*Aquilegia* species	Columbine
G	*Arctostaphylos uva-ursi*	Kinnikinnick
L, F	*Arisaema* species	Dragonroot
W	*Arisaema triphyllum*	Indian turnip
F, L	*Arum* species	
F, W	*Arum maculatum*	Cuckoopint
W, F	*Asarum canadense*	Wild ginger
T	*Astilbe x arendsii*	False spirea
F	*Athyrium filix-femina*	Lady fern
A	*Begonia semperflorens*	Annual begonia
A	*Begonia x tuberhybrida*	Hybrid tuberous begonias
F, G	*Bergenia cordifolia*	Heart-leaf bergenia
A	*Browallia speciosa* 'Major'	Sapphire flower
T	*Caltha palustris*	Marsh marigold
W, L	*Chrysogonum virginianum*	
W, T	*Cimicifuga racemosa*	Black snakeroot
A	*Coleus bungei* cultivars	Coleus
G	*Convallaria majalis*	Lily-of-the-valley
S	*Cornus alba*	Tatarian dogwood
S	*Cotoneaster* species	(Deciduous types)
F, L	*Dicentra eximia*	Wild bleeding heart
F, T	*Dicentra spectabilis*	Bleeding heart
B	*Disporum flavum*	Fairy bells
L	*Dodecatheon pulchellum*	Shooting star
F	*Dryopteris filix-mas*	Male fern
G	*Duchesnea indica*	Mock strawberry
F, G	*Epimedium* species	Barrenwort
E, B	*Eranthis hyemalis*	Winter aconite
B	*Erythronium grandiflorum*	Avalanche lily
S	*Euonymous fortunei*	Winter creeper
S, E	*Forsythia suspensa*	Golden bells
S	*Fothergilla major*	Witch-alder
E, B	*Galanthus nivalis*	Snowdrop
G, E	*Galium odoratum*	Sweet woodruff
G	*Hedera helix*	English ivy
E	*Helleborus* species	Hellebore
W, E	*Hepatica americana*	Liverleaf
S	*Ilex x meserveae*	Holly
A	*Impatiens wallerana*	Busy Lizzy
L	*Incarvillea delavayi*	Hardy gloxinia

Code	Botanical name	Common name
W, F	*Iris cristata*	Dwarf crested iris
B	*Iris reticulata*	
G	*Lamiastrum galeobdolon*	Yellow archangel
B	*Leucojum vernum*	Spring snowflake
T, B	*Lilium* (various)	Lilies
A	*Lobularia maritima*	Sweet alyssum
G	*Lysimachia nummularia*	Moneywort
T	*Lysimachia punctata*	Yellow loostrife
G, S	*Mahonia repens*	Dwarf Oregon grape
F	*Matteuccia struthiopteris*	Ostrich fern
T	*Mertensia virginica*	Virginia bluebells
A	*Mimulus x hybridus*	Monkey-flower
B	*Muscari* species	Grape hyacinth
S	*Nandina domestica*	Heavenly bamboo
B	*Narcissus* (selected types)	Daffodil
A	*Nicotiana alata* (Nicki strain)	Flowering tobacco
A	*Nierembergia hippomanica*	Cupflower
F	*Osmunda regalis*	Royal fern
G	*Pachysandra terminalis*	Japanese spurge
W, E, L	*Phlox divaricata*	Blue phlox
S	*Pieris forrestii*	Chinese pieris
W, F	*Podophyllum peltatum*	Mayapple
W, L	*Polemonium foliosissimum*	Leafy Jacobs Ladder
T, W, F	*Polygonatum biflorum*	Small Solomons seal
E	*Primula x polyantha*	Polyanthus
L	*Primula* species	Primrose
F, L	*Pulmonaria officinalis*	Lungwort
S	*Rhododendron carolinianum* 'PJM'	Carolina rhododendron
A	*Salvia splendens*	Scarlet salvia
F, W	*Sanguinaria canadensis*	Bloodroot
F, G	*Saxifraga stolonifera*	Strawberry geranium
B	*Scilla hispanica*	Spanish squill
G	*Sedum spurium*	Stonecrop
S	*Taxus x media*	Yew
A	*Torenia fournieri*	Wishbone flower
E, W	*Trillium* species	Wake-robin
T	*Trollius europaeus*	Globeflower
B	*Tulipa* species & varieties	Tulip
B	*Uvularia grandiflora*	Bellwort
S, E	*Viburnum x carlcephalum*	Fragrant snowball
G	*Vinca minor*	Creeping periwinkle
L	*Viola pedata*	Birdfoot violet
A	*Viola x wittrockiana*	Pansy
G	*Waldsteinia fragarioides*	Barren strawberry

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FOCUS ON Cassava IN BOETTCHER MEMORIAL CONSERVATORY

by Peg Hayward

Cassava, belonging to the genus *Manihot* of the euphorbia family, is native to tropical America where the roots have been an important source of food from early times. *Manihot esculenta* Crantz, bitter cassava, has been introduced into most tropical regions where it is cultivated extensively for starch.

Cassava or manioc is a perennial herbaceous shrub with slender woody stems growing up to 9 feet high. Long stalked leaves are usually deeply lobed. Inconspicuous flowers less than ½ inch long are in panicles. The fleshy tapering roots with potatolike tubers may be 3 feet long and 9 inches in diameter. Cassavà roots produce higher yields of carbohydrates than maize or rice. A single plant may yield 10 pounds of starch.

The tubers contain dangerous amounts of hydrocyanic acid, a poison which is dissipated with cooking. American Indians devised methods—peeling, shredding, soaking in water—to effectively rid the tubers of the poison and convert them into useful food. When the roots are ground and the starch washed out and then heated until the granules explode to form small lumps, the result is tapioca. The starch can be ground to make flour and Brazilian arrowroot, which are used in making cakes and bread and for

Cassava, *Manihot esculenta*

thickening soups and sauces.

The protein value of the tubers is low. Nutritional value is increased if the leaves are used as pot herbs, but if the leaves of the cassava are harvested as a leaf vegetable there is a decrease of tuber production. The leaves are pounded before cooking and then cooked 1 or 2 hours to rid them of the bitter flavor.

It is unfortunate that the cassava plant, though easily grown, exhausts the soil and cannot be grown profitably for more than 3 succesive years in the same ground. Cassava is sometimes grown from seed when raised commercially, but the more common practice is to plant pieces of the stem. In regions subject to frost the canes are buried until spring and are then cut into 5-inch lengths and planted. Roots do not keep well after being dug so are allowed to remain in the ground until processing.

Peg Hayward, long associated with the guide training program for Boettcher Memorial Conservatory, writes "Focus On" as a regular feature of *The Green Thumb*.

Cassava can be divided into bitter and sweet varieties. Roots of the sweet are eaten like potatoes. In parts of Africa and India the roots provide a source of starch for commercial purposes such as the paper and textile industries. Other varieties are recognized and given local names in different countries. They may differ in foliage, size and color of tubers, and character of stems. Some are grown as ornamental plants.

Cassava is now the subject of extensive research because of its capacity to produce high yields of calories.

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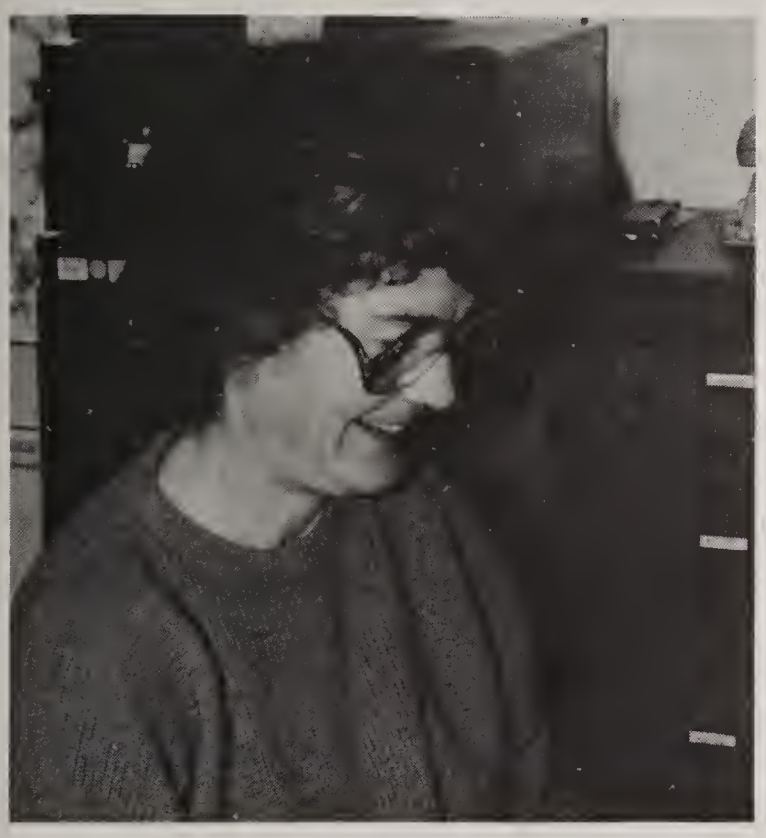

Beverly Nilsen: Our First 25-Year Staff Member

Though young in years, Beverly Nilsen is our longest-serving staff member.

While attending the University of Denver as an art major, she took a course in botany and found it so interesting she decided to pursue an education in plant science. After graduation and during the "budding days" of Denver Botanic Gardens she became secretary for Dr. A. C. Hildreth, first director to develop the York Street site. With a limited staff at the Gardens in 1961, the need for multi-talented personnel was vital. Her other responsibilities included bookkeeping, assisting with membership records, working on *The Green Thumb,* designing flower beds, supervising some work on the grounds, conducting test programs and keeping track of the plant materials.

In 1969 she was promoted to Botanist-Horticulturist; record keeping and plant testing continued. She was also designer-coordinator of the Gardens' plant exhibits at the Garden and Home Shows, coordinator of the Children's Garden program for many seasons, and All-America rose selection judge for almost a decade. Whether staff or volunteer, over the years she has served on various committees.

As the Gardens grew so did the plant records and by late 1970s that was her primary responsibility. All of the record work was done on file cards until 1984 when the bulk of record keeping was transferred to computer to provide greater efficiency in record keeping and information retrieval. Under her jurisdiction, as well, are the herbarium and mycological collections.

Congratulations, Beverly Nilsen, on your Silver Anniversary with Denver Botanic Gardens. It is our pleasure.

"The river forms a green silk belt, the mountains are like blue jade hairpins"
—The poet Han Yu (A.D. 768-824) describing the Guilin area

The Li River

Reminiscences of A Horticulturist in China—II

by Merle M. Moore

Southwest of Beijing in one of China's richest agricultural plains lies the city of Chengdu, capital of Sichuan Province. Perhaps best known to Americans for its most delectable and spicy cuisine, Sichuan is also China's most populous province—the population of Chengdu alone is nearly 4 million. The cultural center of southwestern China, Chengdu has more than a dozen institutions of higher education including the prestigious Sichuan University. The city is also home to the world famous Sichuan opera with performances including music, dance and acrobatics.

Having left the more temperate climate of Beijing and come to the subtropics of southcentral China, I was struck upon our arrival at the Chengdu airport by the change in temperature and humidity. It was disheartening to learn that the pall of smoke so noticeable at the airport and which hung over the city of Chengdu during our entire visit there was the result of burning many acres of paddy to destroy a devastating disease in the ripening rice crop. It is not uncommon in Asian countries to burn the stubble of rice plants following harvest, thus returning some nutrients to the soil and making it easier for water buffalo to pull a plow through the soil when preparing the paddy for a subsequent crop. In this instance, however, the rice was being burned before harvest with the loss of the season's entire crop.

Our first full day at Chendu was spent in the conference facilities of the Jin-Jiang (Brocade River) Hotel where members of our delegation presented papers on design of parks and open spaces, current research on tree pruning techniques, and the latest methods of tree fertilization. During the remainder of our stay we visited several parks and gardens accompanied by officials of the local research institutes of forestry and horticulture.

At a shrine commemorating the Tang

Merle M. Moore, executive director of Denver Botanic Gardens, has a keen interest in both the peoples and the flora of Asian countries.

Part I of "Reminiscences of a Horticulturist in China" appeared in *The Green Thumb* 43(2).

Chinese couple being photographed in front of thatched cottage of the poet Du Fu

Dynasty (712-770 AD) Poet Du Fu, the 50 acres of surrounding garden were intricately laid out and planted to give one the feeling of walking through many "out-door rooms." Interesting walkways, pergolas, hedges and walls made extensive use of bamboo. A replica of the poet's thatched cottage sits alongside "The Flower Bath Creek" and is a popular spot not only with those studying Du Fu's many works that are preserved at this shrine but also with young Chinese couples looking for an interesting back drop for a photograph.

Here, as in most of the gardens visited, there was an obvious lack of modern grounds and plant maintenance equipment we take so much for granted. As I observed a group of workers mixing chemical insecticide in a bicycle-mounted sprayer, without benefit of safety gear to prevent inhaling the toxic fumes or splashing the chemical solution on their hands and arms, I was reminded how workers in nurseries, greenhouses and gardens in our country were exposed to the same risks before the Occupational Safety and Health Act prohibited such dangerous practices.

Wanjianglou, River View Pavilion Park, was a very pleasant and restful place also dedicated to a Chinese poet: a woman—Xiue Tao. Dating to the Ming Dynasty (1368-1644 AD), the main at-

Bicycle-mounted pesticide sprayer

tractions there were a diverse collection (over 120 varieties) of bamboo and the beautiful three-story wooden pagoda in an architectural style of South China. Growing in this garden is tortoise shell bamboo, *Phyllostachys pubescens* var. *heterocycla,* referred to by our guide as "man-face" bamboo. A piece of this unusual bamboo is used at the northeast entrance to our Japanese Garden just overhead as you respectfully bow to pass through the low gateway there.

Sichuan Province, with its extensive forests of bamboo, is noted for the many types of bamboo-ware and baskets produced both for local use and world-wide distribution. Making furniture and other bamboo products employs large numbers of people in Chengdu and the techniques used go back thousands of years. Small pieces of bamboo with numbers (in Chinese characters) painted on them aid the bicycle attendants in sorting out the hundreds and thousands of bicycles left in the parking areas near shrines, parks and in the downtown sections of cities. Once the number is painted on a flat piece of bamboo it is split in two, a hole drilled in the end of each half and a string attached. When one leaves his bicycle with an attendant he is given one half of the bamboo piece and the other is tied to the handlebar. When the owner returns he needs only to match the two bamboo halves to reclaim his bicycle. The charge assessed by the attendant for this bicycle tending service is 2 fen = 1/50th of a yuan = .8 of 1 U.S. cent.

24 Bamboo bicycle identification marker

The bamboo forests of Sichuan Province are habitat for the giant panda, 13 of which are on display at the Chengdu Zoo. One of our hosts, Mr. Li Zhengrong of the Department of Agriculture and Animal Husbandry, pointed out that the bamboo, *Sinarundinaria nitida,* the panda's primary source of food, flowers at about 60 years of age and then dies. In 1980, Chinese scientists found 140 dead pandas in the high mountain bamboo forests of Sichuan Province. It is believed they perished when the bamboo of that particular forested region flowered en masse and died shortly thereafter, depleting the panda's food source.

A botanical garden, the first in Sichuan Province, has been built recently on the site of a former forest farm just outside Chengdu. While much work had been done to build retaining walls, drainage ditches and concrete walkways, they were only beginning to get preliminary plantings established. With their rolling terrain, some of it quite steep, and the heavy, poorly drained native soils, much work lies ahead to create a botanical garden on that site.

From Chengdu we continued our journey south into the heart of Yunnan Province, home to more than 20 of China's 55 minority nationalities many of whom inhabit the rugged mountains northwest of the provincial capital city, Kunming. Although I was unaware of it at the time, negotiations were underway between Denver and Kunming officials for Kunming to become a Sister City of Denver early in 1986. After experiencing Kunming's setting with its beautiful views of the nearby mountains and its delightful climate (the mean annual temperature is 63°F), we felt a real sense of the appropriateness of Kunming as a Sister City to Denver.

Kunming is also one of China's most

Skyline of the city of Kunming, Denver's newest sister city

culturally and historically important cities. The "Longtan Men" inhabited the Kunming area in the paleolithic age. Bronzeware dating back to the Western Zhou Dynasty (1066-256 BC) has been excavated from ancient ruins and is recorded evidence of an early, sophisticated culture in Yunnan.

The harvest season was much in evidence as we drove through the countryside outside Kunming. Upon the sun-warmed walls of the rural houses and buildings constructed of dark-brown earthen blocks similar to the adobe architecture of our southwestern United States hung brightly colored strings of chili peppers, corn and tobacco leaves to dry. In the communal drying-yards of the villiages corn, beans and rice were spread out like the squares on a quilt while squashes and melons were piled on rooftops awaiting transport to market or storage for later use. These scenes of Yunnan Province at harvest time will always remain one of my most treasured memories of our journey to China.

Corn and rice drying in a communal drying-yard

Equally memorable was the opportunity to present my paper at the Kunming Institute of Botany. Entitled "Landscaping With Rocky Mountain Native Plants," I discussed native plant habitats occuring in Colorado and some of the specific plants from these varied habitats that we have brought into cultivation at Denver Botanic Gardens. Special emphasis was given to our interest in drought tolerant plants and their use in attractively designed landscape settings. Mr. Guan Kaiyun, assistant director of the Institute and interpreter for my presentation, was particularly interested in alpine plants and we have continued to correspond since my return. Mr. Guan has also sent us the Kunming Institute's seed list to initiate an exchange of seed of Rocky Mountain plants and of plants from the mountains of Yunnan Province.

New glasshouses for both displaying and growing plants were being constructed at the Institute—this in contrast to the more frequently observed structures and equipment of considerable age generally lacking in adequate maintenance. A new section was also being added to the botanical garden and of particular interest was an herb garden containing over 500 species of Chinese medicinal plants. Among these were: *Rauwolfia yunnanensis,* whose roots produce a medicine for the prevention and cure of hypertension; *Hemsleya amabilis,* whose tuber mainly contains 23- and 34-dihydrocucurbitacin F, an antibiotic and dephlogisticating medicine; *Tripterygium hypoglaucum,* with roots that yield a medicine for curing rheumatism; *Cyanchum otophyllum,* recently found to produce medicine used to treat epilepsy and neurasthenia; and *Luculia gratissima,* a stunning ornamental plant with large clusters of fragrant, creamy-pink blossoms, whose flowers and fruits can relieve cough and reduce phlegm and whose roots can improve blood circulation and reduce inflammation.

The Kunming Botanical Garden places major emphasis on collecting and evaluating ornamental plants of subtropical and alpine regions of Yunnan Province. Camellias, rhododendrons and orchids along with plants of economic importance are among the larger collections. Magnificent specimens of China-fir, *Cunninghamia lanceolata,* lined both sides of the path in one section of the garden, and 60 foot specimens of deodar cedar, *Cedrus deodara* in another. Some plants, *Camellia reticulata* f. *simplex* for instance, are of interest for several reasons; in this case for beautiful rose colored flowers as well as oil bearing properties.

About 250 species of rhododendrons are found in Yunnan Province—54 percent of the total number of rhododendron species growing in China. The brilliant orange-flowered *Rhododendron molle* is treasured for both its ornamental and its medicinal values. Its use in Chinese medicine was recorded as early as the Jin Dynasty (265-439 AD).

Both terrestrial and epiphytic orchids grow in Yunnan Province, terrestrials

Flowers of *Alocasia* sp. in the medicinal plant section of the Kunming Botanical Garden

under the evergreen broad-leaf trees of the subtropical areas and epiphytes in the sub-canopies of the evergreen rain forests of the tropical areas. Two rare orchids of the region are *Paphiopedilum dianthum,* a pale pink and green flower with gracefully twisted sepals and *Phalaenopsis hainanensis,* a charming, diminutive, pink and cream flowered variety.

Following our tour of the botanical garden, Mr. Chu, a member of the Institute's staff, discussed the development of camellia culture in China, which dates back 600 years. Historically, about 38 cultivars of camellia have been used in Chinese gardens. Current research focuses on locating new forms of camellia in the wild that can enhance fragrance, that will tolerate a wide range of temperatures, and that are more dwarf in habit. More than 82 new varieties are under study and evaluation.

With its excellent botanical garden, beautiful setting and climate, fascinating scenery in the surrounding countryside, and its Sister City relationship with Denver, Kunming will be a highlight of our Botanic Gardens tour to China in October 1988.

As we waited at the Kunming airport for our flight to Guilin, I was amused by the similarity between the "foreign-visitor" waiting areas in the various Chinese airports. The walls were invariably hung with paintings mounted on scrolls, each having its price tag prominently affixed. Overstuffed furniture mixed with plain wooden chairs and tables provided the only respite for those waiting out the inevitable delay in departure. It did not take long to learn the airport waiting lounge was a great place to catch up on tour logs, write a letter or a few post cards, read or grab a nap. The Kunming airport provided one unique diversion—watching the Chinese Air Force pilots practice taking off and landing their outdated MIG jet trainers. It was a not-too-subtle reminder that we were only about 400 miles north of Hanoi, and that China and Vietnam are not what one could consider peaceful neighbors along that border.

As our plane circled the Guilin airport on its final approach I caught my first glimpse of the incredible limestone karst formations that abound in this region. Since the Tang Dynasty (618-907 AD) the Chinese have revered these enchanting

Foreign visitors waiting lounge at the Kunming airport

and haunting rock formations giving them names to equal their beauty. "Wave Conquering Mountain" which stands in the LiJiang (Li River), "The Overlapping Brocade Mountain," "The Bright Moon Peak," "The Flower Bridge," and "The Elephant Trunk Mountain" are but a few examples. Over centuries the combined forces of sedimentation, uplift, dissolution and erosion have sculpted this entire region not only with dramatic uplifted mountains but also with enormous caves resplendent with stalactite and stalagmite formations that defy description. Not to be outdone, they too have been given names such as "The Reed Flute Cave," "The Cave of the Reflected Moon," and "The White Stork Cave" and have been further embellished with the trappings of folklore nurtured by the elders living in small villages that lie in close proximity to the caves.

We visited Guilin in October when the subtropical climate was most bearable rather than in May and June when it can rain for days on end. At the same latitude as Miami, Florida, and only 500 feet above sea level, Guilin can be oppressively hot and muggy at certain seasons of the year. An important refuge during World War II, Guilin's caves became home to the resistance movement with hospitals, newspapers, even theatrical companies housed there.

The stunning geologic features that make Guilin a popular tourist attraction also account for the need to irrigate the arable land of the region. A deep and extensive underground river system and highly porous soils combine to quickly drain surface water away from cultivated crops. More than 2,000 water control and irrigation projects feeding off the Lin Canal provide the means to irrigate thousands of acres of grain, rice, pomelos, and cassia which plays an important role in the production of herbal medicines, tea, a fragrant oil and a distinctively flavored wine. The Lin Canal, constructed during the Qin Dynasty (221-206 BC), linked the Xiangjiang, a tributary of the Yangtse River in Central China, and the Pearl River via the Li River. Although the historical motivation for this enormous engineering feat was military access to the region, today the Lin Canal is a life line contributing to agricultural stability and prosperity in the region.

Our welcome to the Guilin Botanical Garden was typical of the receptions we received at each institute and garden we visited. After our being served hot tea, Mr. Ma Fuqi, director of the Guilin Gardening Bureau, made the following remarks:

"The Horticultural and Botanical Societies of Guilin welcome the third section of the horticultural delegation.

 Limestone karst formations form a dramatic backdrop for the city of Guilin

Rice paddies near Yangdi, along the Li River

The Horticulture Society has received friends but this is the first technical discussion. We hope the exchange will be beneficial for both Americans and Chinese. We also hope the exchange this afternoon will further promote exchanges, friendship and understanding."

As one might expect, given the circumstances of soil and climate in the region, the Guilin Botanical Garden has, since 1978, concentrated on cultivating lime-loving plants. This emphasis in collecting and research has already yielded one publication titled *Illustrated Register of Lime-Stone Plants.*

A small section of the garden is attractively laid out and planted to encourage local visitors. This, I felt, was in contrast to the feeling one had visiting the botanical gardens in Kunming and Chengdu even though we were warmly received in those gardens. Such features as a fern grotto and a pond garden have design elements similar to those observed in the Beijing Botanical Garden which is visited by hundreds of thousands of Chinese each year. Ornamental plants are much in evidence in this section of the garden; *Clerodendron wallichii* is a particularly striking example growing at the pond's edge. Mr. Liang Chenfeu, our guide on the tour of the garden, was obviously quite proud of the many fine specimen trees in their collection. There are magnificent specimens of Chinese palm, *Livistona chinensis,* Chinese empress tree, *Paulownia fortunei,* and *Keteleeria calcarea* with its yew-like *(Taxus ssp.)* foliage. As at previous botanical gardens we visited, medicinal and other economic plants, particularly fruit and oil-bearing types grow here. A beautiful, orange-yellow flowered osmanthus, *Osmanthus fragrans* var. *aurantiacus,* would later be remembered as I enjoyed the delectable flavor of osmanthus-flower wine during our farewell banquet in Guangzhou.

Very few of the 1300 species of plants being grown and studied at the Guilin Botanical Garden are non-native species. A staff of 250, more than half of whom are botanical scientists and technicians, have amassed an herbarium collection in excess of 300,000 specimens and have identified and named 7,024 species of the approximately 8,000 species considered to be extant in the Guangxi Zhuangzu Autonomous Region, so named for the Zhuang (a Muslim people) who inhabit the region and who comprise China's largest minority group (12 million in all). Clearly, taxonomic research has a very high priority in all the botanical insti-

Chinese empress tree, *Paulownia fortunei,* in the Guilin Botanical Garden

tutes in China. A significant effort to identify all the indigenous flora of China is well underway with publication of the *Flora of China,* estimated to consist of more than 130 volumes when completed, being the ultimate goal. (A five volume conspectus of the *Flora of China* is currently available in Denver Botanic Gardens' library.) The important taxonomic work of the staff at each of China's 21 botanical gardens makes this goal attainable.

Before leaving Guilin our delegation was treated to a cruise on the Li River; a never to be forgotten experience! Our multi-deck excursion boat provided ample opportunity to enjoy close-up, not only the incredible limestone karst formations through which the river meanders, but also the human side of life along and on the river. Boat horns, bells and signal flags contributed to a festive atmosphere on board, and a delicious meal served enroute added to a very pleasurable day-long experience. Along the riverside are numerous small farming and fishing villages with plantings of citrus (calamondin oranges, tangerines and pomello), cassava, jute and persimmons interspersed among the usual rice and vegetable crops. On the river fishermen were using poles to propel rafts made from 3- or 4-foot long bamboo poles lashed together; others were using the rafts to harvest water weeds from the shallows near the shore. Cormorants were sleeping perched on the bow of some of the rafts awaiting another evening of diving for fish for their owners. It was in all respects a river journey indelibly imprinted in my memory and one I look forward to sharing with other Denver Botanic Gardens members as we repeat the journey during the Gardens' upcoming tour to China.

I felt a rush of mixed emotions as we flew from Guilin to Guangzhou, our last destination within The People's Republic of China. Not wanting the journey to end, yet eager to return home and share my experiences with those awaiting my return, I felt a deep sense of gratitude that the trip had gone so smoothly and that I had been able to represent Denver Botanic Gardens as a member of the delegation.

Cruising the Li River between Yangdi and Yangshuo

Guangzhou, easily reached from Hong Kong by air, train or boat, is the major foreign trade center in South China, and it boasts a population of 5.3 million. Yet, it is a city of beautiful parks and shrines and a gastronomic paradise for lovers of the subtly flavored and exquisitely presented Cantonese cuisine. In our all too brief stay in Guangzhou we managed to include visits not only to the Botanical Garden of the South China Botanical Institute, but also to the Chen Family Shrine, West Garden, Guangzhou Orchid Garden, Cultural Park—where a horticultural exhibition was underway—and even a quick walk through one of the semi-annual Chinese export commodities fairs which draw more than 25,000 foreign business representatives to Guangzhou each spring and fall.

Mr. Wu Zechun served as our horticultural guide and interpreter during our visit; and judging from his many titles (Senior Engineer of Landscape Architecture, Vice President of the Chinese Society for Horticultural Science, Councilor of the Chinese Gardening Society, and General Engineer for the Guangzhou Landscape Design and Planning Institute) he was eminently qualified to do so. As we drove from place to place Mr. Wu pointed out various street trees being used in the city. Among the more interesting were three varieties of fig, *Ficus wrightiana, F. macrocarpa,* and *F. lacor;* camphor tree, *Cinnamomum camphora;* bottlebrush tree, *Melaleuca leucadendra;* Chinese palm, *Livistonia chinensis;* and *Bombax malabaricum* which blooms with large red flowers in April and is considered the city flower of Guangzhou.

At the West Garden Mr. Wu was quick to point out that the Japanese horticultural art form of bonsai was learned from the Chinese. Called "pon-ching" by the Chinese, they historically have expanded the concept beyond merely growing dwarfed plants in pots to also include growing dwarfed plants on stone, in water or in miniature landscapes. More than 130 species of plants are represented in the pon-ching collection at the West Garden; elm, barberry, buckthorn, ginkgo, crape myrtle and several species of pine were among those observed.

A long alleé of perfectly matched 22-year old royal palms, *Roystonea regia,* made a dramatic introduction to the botanical garden; this species is one of nearly 80 species and varieties of palms under cultivation there. Concentrating on the introduction of tropical and sub-

School children touring the South-China Botanical Garden

tropical economic plants, the Botanical Garden of the South China Botanical Institute has more than 4,000 plants in its collections. The attractively landscaped grounds were crowded with groups of school children of varying ages, who seemed to be far more interested in us than the plants they were undoubtedly there to study. The garden contains a number of buildings, both for exhibition and the restful pleasure of visitors. Several of these structures are adjacent to a large artificial lake in the center of the garden. Growing at the lake's edge is an impressive grouping of bald cypress, *Taxodium distichum,* from southeastern United States, and in a similar spot are several *Glyptostrobus pensilis,* considered to be ancient relict trees.

The bamboo collection is extensive with nearly 100 native species represented. More than 200 species of epiphytic, lithophytic and terrestrial orchids are cultivated in research greenhouses and lath houses in the garden. Among the more unusual trees are the sausage tree, *Kigelia pinnata,* introduced from Ghana, and an Indonesian member of the pea family, *Calliandra surinamensis,* with beautiful white and scarlet tassel-like flowers standing upright above the foliage. For one interested in tropical and subtropical plants a series of visits to this garden over several days would be necessary to fully comprehend and appreciate the plant collections that are represented. Impressive collections of gymnosperms (130 species, chief among them *Gnetum, Podocarpus,* and *Cycas*), cactus and succulents (nearly 500 species), and shade plants are found in the garden's well designed, landscaped displays providing a rewarding and enjoyable experience for the professional botanist/horticulturist as well as the casual tourist.

All too quickly the end of our journey to The People's Republic of China was upon us. We said goodbye to the representatives of the Chinese Academy of Science and Technology, who worked so hard to make our short time in China valuable to us and to our Chinese counterparts in the five geographical regions we visited; then we boarded the train that would take us across the border to Hong Kong. With only one full day in what has to be the most fascinating city in Asia, if not in the world, we hastened to do some last minute sightseeing, shopping and exchanging of addresses along with promises to keep in contact with one another after returning to our respective homes and work in the States.

I had gone to China looking forward with great anticipation to encountering first hand the people, the culture and the natural beauty that I had expected to find there as a result of many years of following with keen interest developments between our country and The People's Republic of China. What I experienced was a warm and friendly people, arts and a culture nurtured and perfected over many centuries, and a vast land of incomparable natural beauty. China was all I had hoped it would be and much, much more! I hope the many contacts I made with colleagues in botany and horticulture there will prove fruitful and of long-term value to Denver Botanic Gardens. I look forward to one day welcoming to Denver some of their botanists and horticulturists so that we might share with them the kind of hospitality I was extended throughout our travels in China. We have much to learn from them about the seemingly infinite botanical and horticultural resources to be found in China; and in return, we can share with them much that we have learned about technological and biological advances in plant propagation and care, landscape planning and design, and park/open space management.

In the final analysis that is what this journey was all about; opening new lines of communication between East and West through the common denominators of our mutual fascination with and interest in plants and their importance to the survival of humankind.

Velcro—
A Nature-Inspired Wonder

by Carolyn Knepp

Growing in fields throughout Europe and Africa is a stubborn weedy plant, the burdock. One of nature's clingers, its burrs appeared to grow for the sole purpose of terrorizing dogs and hunters until George de Mistral was inspired by its magical adhesive characteristics. After a day of hunting in the Swiss mountains and removing burrs from his dog's coat, de Mistral became intrigued by this clinger.

The burdock, *Arctium minus,* can be found growing extensively in fields, along fences and roadsides, and in many disturbed areas. Indigenous to Europe and Africa, this hitchhiker has been successfully introduced to North America. As late as the mid-1940s the pest was difficult to locate in the Denver region, but now it is prevalent in waste places. Two other introduced burdocks with the same characteristic hooked burrs occur, but much less commonly, in similar habitats especially in eastern states.

Numerous small pink to purple tubular flowers surrounded by hooked bracts cover the head. In late summer the flowers drop off leaving behind tough barbed burrs to challenge intruders—just in time for the hunting season. *Arctium* is Greek for bear and probably refers to the brown shaggy burrs but may imply that they are a "bear" to remove.

Close examination of the burr reveals hundreds of tiny hooks, a discovery that led de Mistral to eight years of research culminating in the development of Velcro. This product consists of two tapes, one with tiny burr hooks and the other a complementary tape of soft nylon loops—a combination that enables the hooks to hold with the strength and stubborness of the burdock burr. Not only will these man-made hooks frighten dogs and cling to sweaters, but they will keep packs secured, clothes fastened and posters on bulletin boards.

Carolyn Knepp, education assistant at Denver Botanic Gardens, is a forestry graduate of the University of Arizona with a special interest in woody plants.

The Green Thumb

Denver Botanic Gardens, Inc.

A Non-Profit Organization

Sent to all members of Denver Botanic Gardens. Membership fees are as follows: Individual Student $18.00, Individual Senior Citizen $18.00, Senior Couple $25.00, Individual $25.00, Family/Dual $35.00, Contributing $50.00, Supporting $100.00, Patron $500.00, Benefactor $1000.00.

By becoming a member of Denver Botanic Gardens, Inc., you will receive *The Green Thumb* and the monthly *Green Thumb News*. You will also have year-round admission to the gardens and unlimited access to the use of the books in the Helen K. Fowler Library, located in Boettcher Memorial Center at 1005 York Street.

For further information, write to Membership Chairman, Botanic Gardens House, 909 York Street, Denver, Colorado 80206, or call 575-3751.

Denver Botanic Gardens, Inc., maintains a collection of living plants, both native and exotic, for the purpose of acquiring, advancing and spreading botanical and horticultural knowledge.

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The Green Thumb

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The Cover

Native Pine
Frances Frakes Hansen

Cut-back in Issues of *The Green Thumb*

Because of budget constraints at Denver Botanic Gardens, there will be only two issues of *The Green Thumb* published in 1987.

—*Editor.*

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How to Know the Coniferous Evergreens

by Helen Marsh Zeiner

Are you one of the many otherwise good gardeners who calls every coniferous evergreen a "pine" or a "spruce"? Why not take time to learn the common evergreens so that you can identify them at least to the genus?

The following key is simple enough to be used by the average gardener. It is by no means a complete key, but it does include the common genera you are likely to encounter in Colorado.

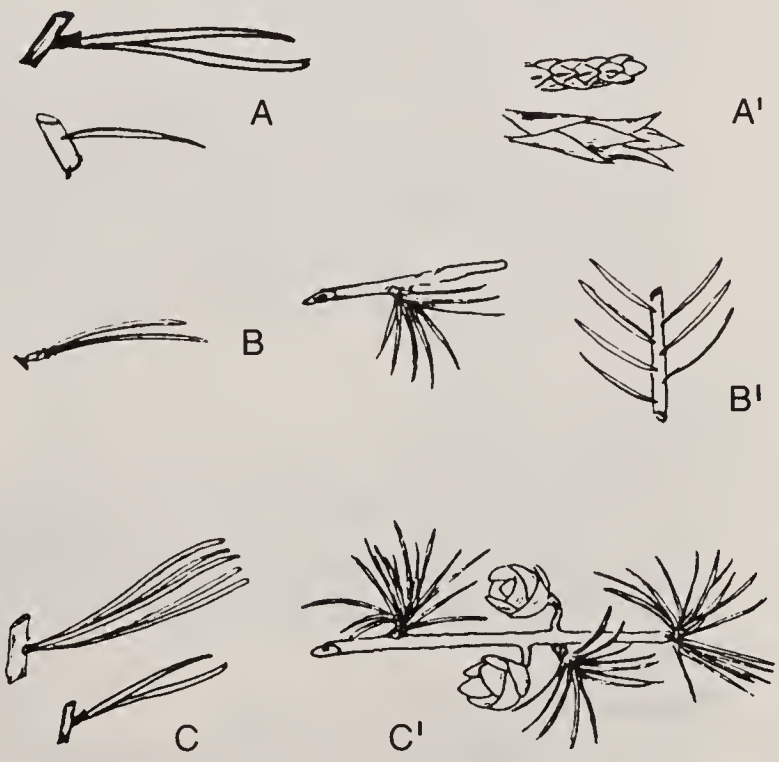
Using a key might be likened to following clues in a treasure hunt in which you must always choose between two clues. If you make the correct choices, you find the treasure. Following a key is also often compared with following a many-forked road in which you must choose between signs at each fork and, choosing correctly, arrive at your destination. Just as one sometimes takes the wrong fork in the road and must retrace one's steps, a wrong choice in the key means backing up and following the other choice.

In the key presented here, your first choice is between the two letter A's. If you choose the first A, then your next step is to decide which B is correct. If you choose the second A, your choice is between the two F's, and so on until you arrive at the name of the evergreen you are identifying.

For those who would like to learn more than the genus, a brief description of common species and their distinguishing characteristics follows the key to the genera.

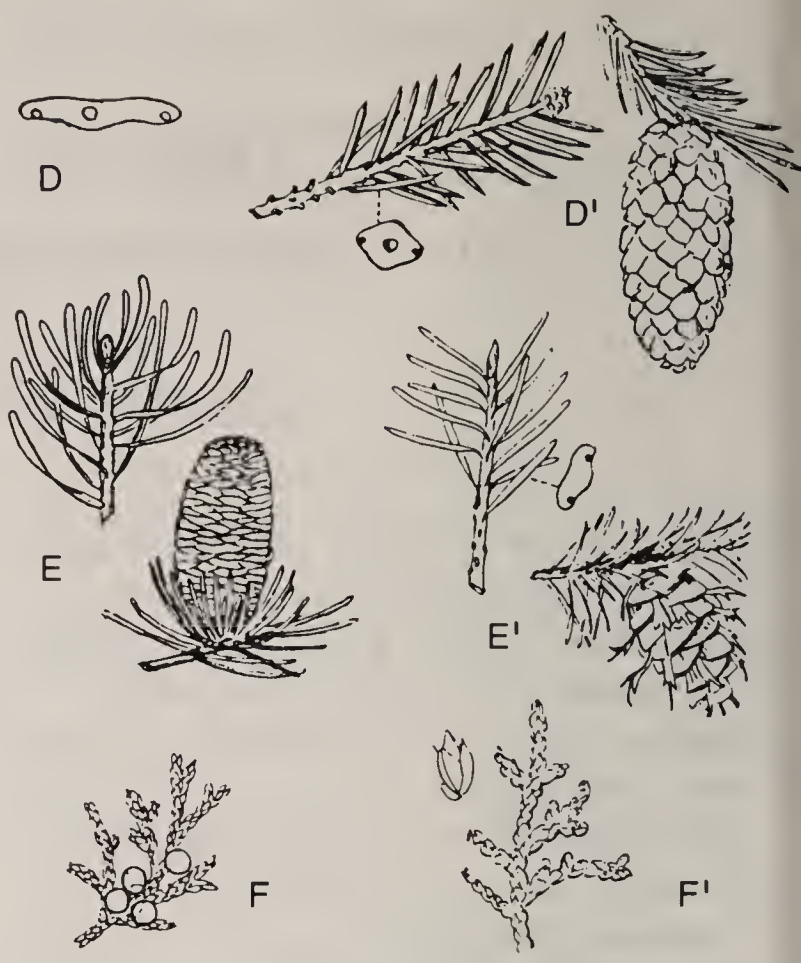
Key to some common genera of Pinaceae and Cupressaceae

A. Leaves needle-like .....B
A'. Leaves scale-like or awl-shaped, not linear .....F
B. Needles borne in clusters at tip of short growth branchlets C
B'. Needles borne singly on the stem..D
C. 2-5 needles in a cluster . *Pinus,* pine
C'. Many needles in a cluster (except on terminal shoots) and falling in the autumn ..... *Larix,* larch



Helen Marsh Zeiner, Ph.D., honorary curator of Kathryn Kalmbach Herbarium, DBG, is a frequent contributor to *The Green Thumb.* This article is a revision of "How to Know the Evergreens," *The Green Thumb* 22(6):193-196.

D. Needles flat .....E
D! Needles diamond-shaped or square in cross-section ..... *Picea,* spruce
E. Base of needles rounded into a "suction cup," buds rounded, twigs somewhat flattened ..... *Abies,* fir
E! Base of needles tapering into a tiny stalk, buds pointed. Cones, if present, bearing a conspicuous 3-pronged bract between the scales .... *Pseudotsuga,* Douglas-fir
F. Leaves awl-shaped, or some awl-shaped and some scale-like, fleshy bluish, berry-like cone ..... *Juniperus,* juniper
F! Leaves scale-like, twigs very flattened as though pressed, cone dry, not berry-like ..*Thuja,* arborvitae, white cedar



Coniferous evergreens native to Colorado

Pinus — Pine

2-3 needles in a cluster

Ponderosa pine *(Pinus ponderosa* ssp. *scopulorum)*
Large tree forming open forests at lower elevations in the mountains. Two or three needles in a cluster, 3″-5″ long, yellow-green. Cones 2½″-3½″ long, bristle tipped. Bark on young trees black, on mature trees in yellowish brown plates.

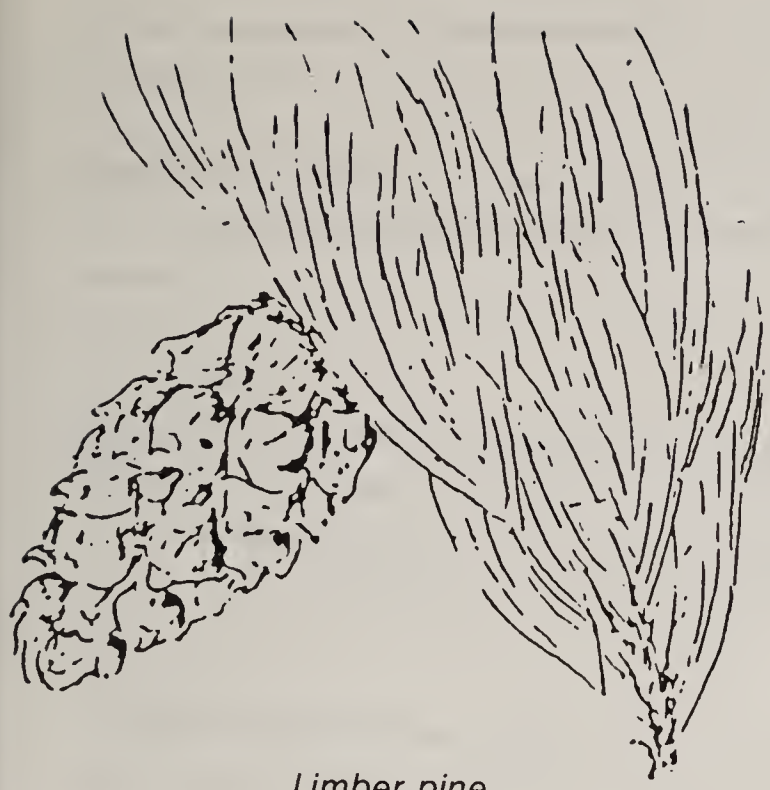
Lodgepole pine *(Pinus contorta* ssp. *latifolia)*
Tall tree with slender, straight trunk. Light yellow-green needles in clusters of two, about 2″ long, tending to curl. Cones 1½″ to 2″ long, tightly affixed to branches and remaining on the tree for years. Thin, scaly bark.

Pinyon pine *(Pinus edulis)*
A low growing tree, sometimes shrubby in appearance. Needles about 1½″ long. Cones to 2″ long, thick scales without bristles that open in August or September to expose the edible seeds. Often planted in Denver. (Singleleaf pinyon, an uncommon tree in southwestern Colorado, resembles pinyon except that it has one needle in a "bundle," the only one needle pine. Needles are round in cross section, another unique feature.)

5 needles in a cluster.

Bristlecone pine *(Pinus aristata)*
Found near timberline or on exposed ridges at lower elevations. Needles 1½″ long, heavy, dark green and dotted with specks of white pitch. Cone scales have bristles or prickles. Cones are 1″-3″ long. Planted as an ornamental in Denver.

Limber pine *(Pinus flexilis)*
Found in the same locations as bristlecone pine and also used as an ornamental. Needles may be 1″-2″ long, grayish to bluish green, rather soft



Limber pine

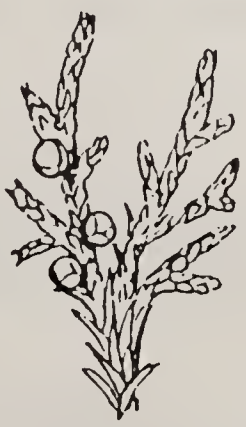
Ponderosa pine

Lodgepole pine

Colorado blue spruce

Pinyon pine

Rocky Mountain juniper



One-seed juniper

Utah juniper

and inclined to curl. Cones up to 6″ long, without prickles. Branches are smooth, light gray and flexible.

Southwestern white pine *(Pinus strobiformis)*

Tall, straight trunk. Needles 3″-4″ long, with a few very minute teeth near the apex. Cones 5″-9″ long, unarmed, on a stalk ½″-⅔″ long. Found in southwestern Colorado.

Picea — Spruce

Colorado blue spruce *(Picea pungens)*

Found along streams in the mountains at elevations of 8000′-8500′. Needles — 1″-1½″ long, stiff, sharp, may or may not be bluish. Cones light brown, 2″-4″ long. The bark is gray, rough and in ridges rather than scales. New twigs are smooth. This beautiful tree is widely planted as an ornamental.

Engelmann spruce *(Picea engelmannii)*

Forms extensive forests in the subalpine zones. Cones smaller than those of Colorado blue spruce. Bark on mature trees is a characteristic cinnamon brown and is in scales, not ridges. New twigs are pubescent, not smooth. Young needles when crushed have an unpleasant odor. It is also used as an ornamental, although not as commonly as the Colorado blue spruce.

Abies — Fir

White fir *(Abies concolor)*

Flat needles 1″-3″ long, vary from silvery to dark green. Sprays of branchlets are noticeably flattened. Cones grayish green, 3″-5″ long, upright on uppermost branches. Cone scales fall while the spikelike axis remains "candlelike" on branch. Sometimes planted as a specimen tree.

Subalpine fir *(Abies lasiocarpa)*

A fir of high altitudes. A narrow, tall tree with needles about an inch long. Branches less noticeably flattened than those of white fir. Cones 2″-4″ long, dark brown-purple.

Corkbark fir *(Abies arizonica)*

Occasionally found at medium altitudes in southwestern Colorado. Very similar to subalpine fir, but the bark is very thick, white, and corky; the needles are usually bluer.

Pseudotsuga — Douglas-fir

Douglas-fir *(Pseudotsuga menziesii)*

Found in association with ponderosa pine, occurring in moister sites at the same elevations. It can be told from spruce by the flat, petiolate needles and the smooth twigs. The bracts on the cones are unique. They have three prongs which resemble the two hind legs and tail of a mouse scurrying for cover under the cone scale. Douglas fir is frequently seen in Denver.

Juniperus — Juniper

Spreading or prostrate, under 6′ tall.

Mountain common juniper *(Juniperus communis)*

Shrub about 1′-3′ high. The awl-shaped needles have a white streak on the side next to the branch.

Erect

Rocky Mountain juniper *(Juniperus scopulorum)*

Most common upright juniper in this area. "Berries" blue or black.

Many ornamental varieties have been derived from this native.

One-seed juniper *(Juniperus monosperma)*

Found in southern Colorado. Coarser in texture and usually darker in color than Rocky Mountain juniper. Foliage scales are more open and do not hug the branches as do the scales of Rocky Mountain juniper. Each one-seeded "berry" or cone is full of liquid resin when crushed. One-seed juniper is usually broadly conical but frequently has many stems arising at or slightly below the surface of the ground, and resembles a bush.

Utah juniper *(Juniperus osteosperma)*

Found in western part of the state. "Berries" are larger than those of any other juniper and are dry and mealy when crushed. Hard to distinguish from one-seed juniper unless there are berries. The several stemmed forms are similar in appearance to one-seed juniper, but the trunklike branches leave the trunk near or above the ground. Old trees are almost round.

Some commonly cultivated, not native, coniferous evergreens

Pinus — Pine

2-3 needles in a cluster

Mugo pine *(Pinus mugo)*

Plant shrubby, not over 10′-13′ tall. Needles two, crowded, stout, 1″-3″ long, bright green. Very common.

Austrian pine *(Pinus nigra)*

Needles 3″-5″ long, dark green, stiff; twigs rigid; bark on old trees dark. Often seen in parks.

Scotch pine *(Pinus sylvestris)*

Needles 2″-3″ long, twigs flexible, bark of branches orange. Shape of tree open.

5 needles in a cluster

Eastern white pine *(Pinus strobus)*

Frequently planted in Denver as an ornamental. The needles are about 3″ long, very slender, soft to the touch. The cones are large, often resin dotted.

Picea — Spruce

Black Hills or white spruce *(Picea glauca* var. *densata)*

Planted quite frequently as an ornamental. Needles are very short, curved, slender and pale green. Cones are slender, about 2″ long.

Juniperus — Juniper

Spreading or prostrate, under 6′ tall.

Pfitzer *(Juniperus chinensis* 'Pfitzerana')

A commonly cultivated juniper with feathery growth. About 2′-6′ tall.

Tamarisk or "Tammy" juniper *(Juniperus sabina* 'Tamariscifolia')

Mounded, seldom over 3′ in height.

Erect

Eastern red cedar *(Juniperus virginiana)*

Similar to Rocky Mountain juniper but has a more open growth and is generally a reddish color in winter. The berries are brownish violet.

Urban Stress In Trees

by James R. Feucht

Stress occurs in all living things whether in their natural habitat or not. Stress is part of life and, in a sense, is a survival factor. It is also a potentially injurious but reversible condition caused by any factor that may drain energy or disrupt life processes. Individual stresses are not usually fatal to living things. More often it is a combination of stresses, their duration and the ability or inability to cope with stress that determines the outcome.

In animals and humans, stress is met by body processes with such changes as quickened heart beat, thus faster blood flow, the development of antibodies to fight encroaching organisms, raising of body temperature and many other reactions. Likewise, trees react to stress by modifying otherwise normal functions. Trees under drought stresses may drop some of their leaves to reduce water loss. Some, like cottonwoods, will even shed small branches, a condition called cladoptosis.

Trees also undergo chemical and physical changes within when stresses occur. These are built-in defensive mechanisms that enable a tree to survive and regain its full potential of energy. To understand this, it is important to examine how a tree is structured and how its defensive mechanisms work. Most of this understanding has come about through the research of Alex L. Shigo, Ph.D., USDA Forest Service Pathologist (ret.). His recent book *A New Tree Biology* (Shigo and Trees, Associates, 1986), is highly recommended for those wishing to gain new facts and a refreshing new philosophy about trees.

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Trees are compartmented structures

Traditionally, we have learned about trees by viewing them in cross-section observing that a tree has a core of wood made up of growth rings and surrounded by a cylinder of bark. The new wood, called sapwood, conducts water and minerals from the soil; the inner bark conveys food materials (carbohydrates) from the foliage. Unfortunately, this concept has led to an incomplete understanding of a tree.

If one looks at a tree in a three dimensional view, a more complete idea is formed. A tree should be thought of as a series of cone-shaped cylinders, one on top of another (Fig. 1). In a sense, a tree is a tree within a tree. Every year a tree makes a new tree and simply buries the old tree. The cylinder is divided radially into compartments by cell layers called rays. The compartments have inner walls formed from old growth rings and outer walls formed from new sapwood (Fig. 2).

In a sense, a tree is made up of more or less vertical wedge-shaped masses of cells of various sizes that are separated by "walls" of cells that form natural boundaries.

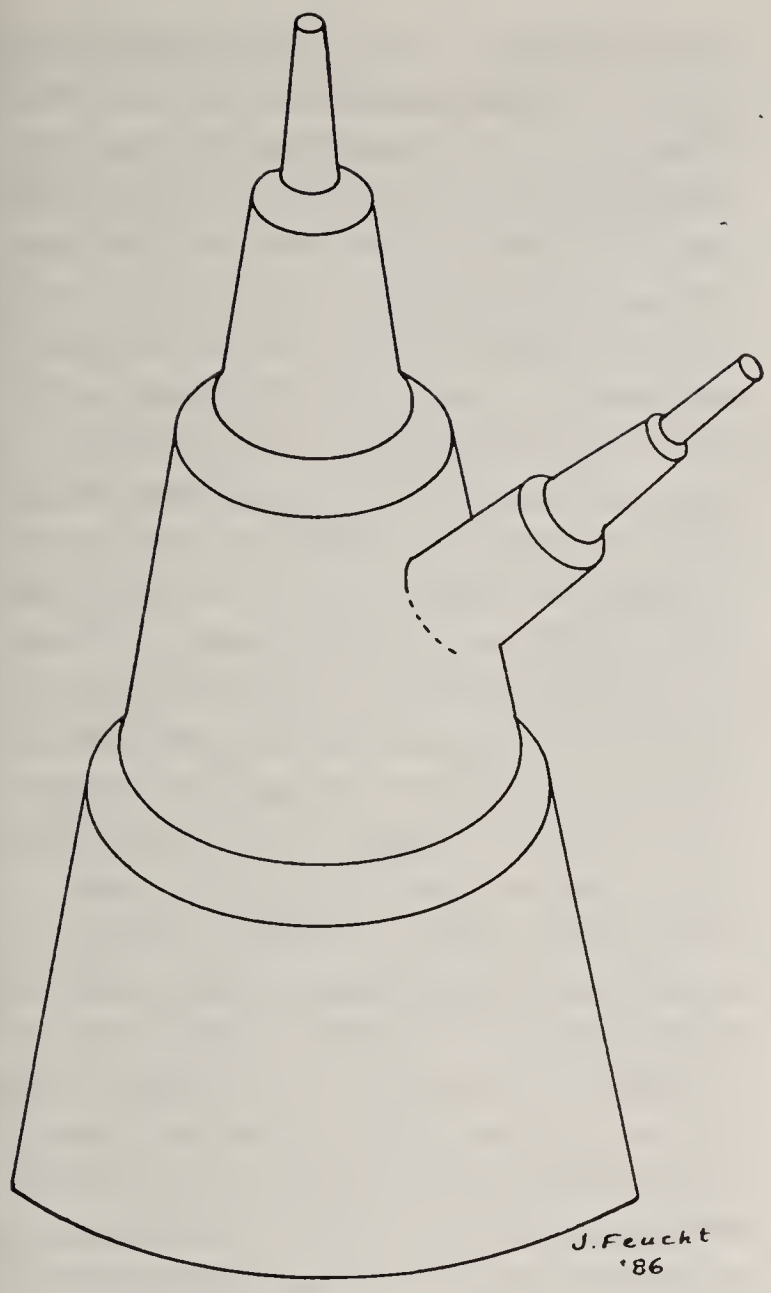

Figure 1. Three dimensional concept of a tree as cone-shaped cylinders.

Defensive mechanisms in trees

When a tree is wounded or an insect or disease organism attempts to invade, the first response of the tree is to compartmentalize or "wall off" the adversity. In the vicinity of the injury and within the confinement of one or more of the compartments mentioned above, both chemical and physical reactions take place. In deciduous tress, phenolic compounds, such as tannins, become concentrated. In conifers, terpenes form. Both chemical groups are highly antimicrobial and thus become an immediate defensive weapon against organisms.

Water-conducting vessels (tracheids in conifers) are also physically blocked by the ballooning of cell wall membranes, called tyloses. The cambium, if healthy, also forms a layer of new, non-conductive cells called the barrier zone. (Fig. 3).

This walling off process is not the same in all trees and is probably very weak in trees that are under severe stress. Thus, some trees successfully fight off invaders, others do not. The key to success is primarily the amount of stored energy remaining in the tree.

Elms are good compartmentalizers

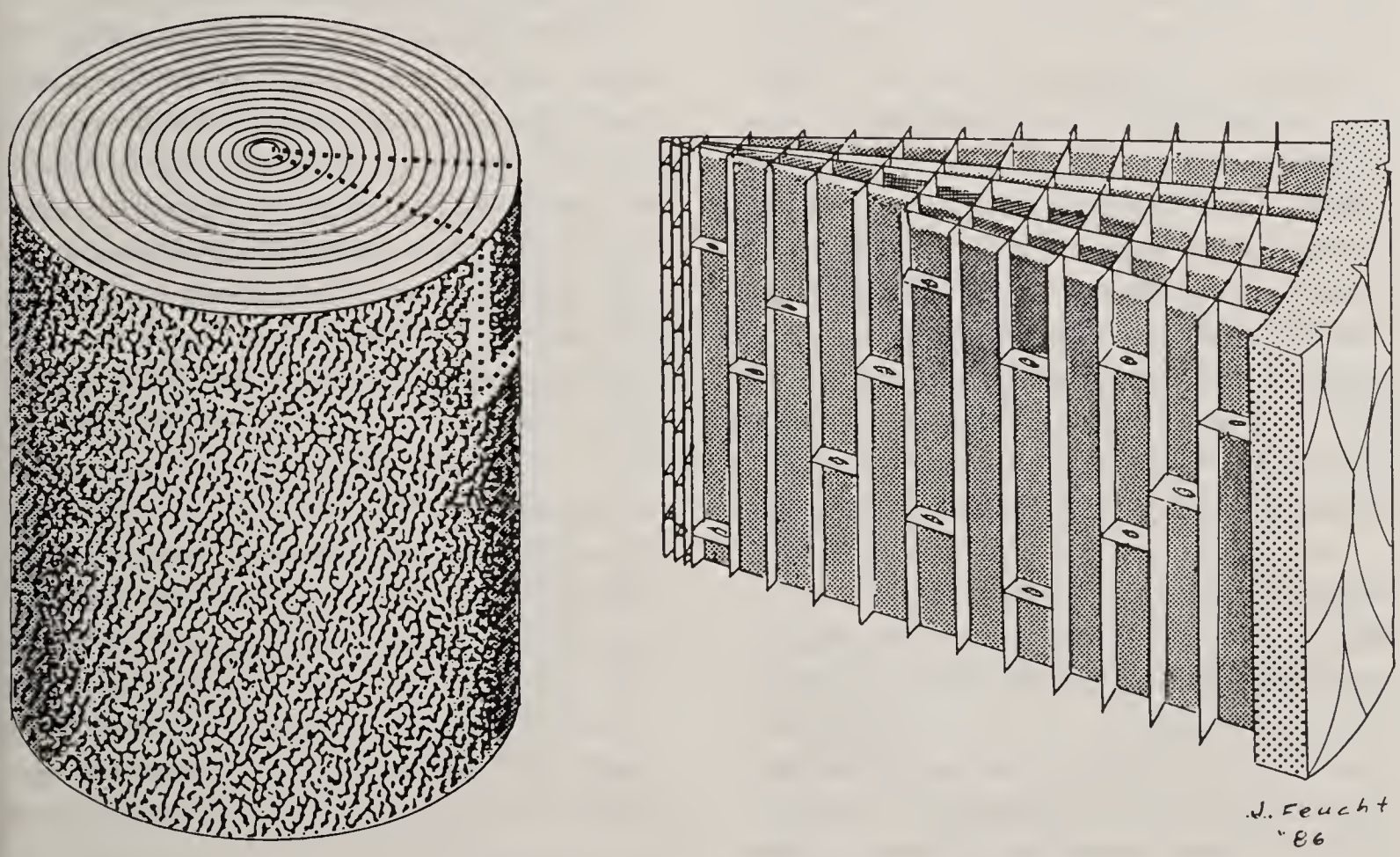

Figure 2. Diagrammatic representation of the wedge-shaped compartments of a tree.

Figure 3. Barrier zone (dark, curved band) is a layer of non-conductive cells formed by the cambium following injury. The wedge-shaped stain in the wood occurs because the ray cells form a boundary walling off the injury.

against Dutch elm disease. The problem is, the organism keeps causing the tree to wall off more and more stored energy and reducing water uptake. Thus, elms actually compartmentalize themselves to death.

Some trees genetically are weak in defensive mechanisms. Aspen, willow and many poplars appear to be weak and thus short-lived due to a poor ability to defend against some pathogens. This is probably why such species are successive (temporary) rather than climax (permanent) vegetation in natural areas.

Domino effect

Reactions to stress in trees are complicated not only by the fact that trees are genetically variable in their ability to ward off adversities, but also by the fact that most declines in trees do not occur as a result of one cause alone. There is a sort of domino effect.

An example is the severe outbreak of cytospora canker in cottonwoods in 1986. Cytospora, a fungus organism, produces spores that many authorities believe are present in the air year around. Spores landing on a susceptible host such as cottonwood will do no harm unless they happen to lodge in a wound. Even then, the tree may successfully wall off the organism if the tree is in good health. If, however, the tree is under stress from drought and cold injury, as was the case in late 1985 and a warm winter follows, as did in early 1986, the organism gains a foothold. The trees were stressed, food energy reserves were reduced by an early freeze and water supply was limited. The tree's defenses were caught off guard. During late winter of 1986, it was observed that the cytospora fungus proliferated beneath the bark, almost surreptitiously, feeding on stored energy of the tree and killing whole branches or even entire young trees. Thus several adverse conditions, one right after the other, led to the decline and death of cottonwoods; early freeze, fall drought and warm winter.

The domino effect is also apparent in other common problems in an urban landscape. A scenario as follows may not be too uncommon in reality: Sod laid on poorly prepared clay soil needs frequent shallow watering to keep it alive. The shallow watering promotes shallow roots. Frequent water applications encourage turfgrass diseases. Fungicides are applied. The fungicides not only control the disease organisms, but destroy beneficial microorganisms that break down thatch. Thatch builds up and water cannot penetrate. Turf insect pests, such as sod webworm, invade the thatch and drought-stressed turf. An insecticide is applied to control the worms. More beneficial organisms die and thatch continues to build up. Grass roots grow up into the thatch for moisture and air. Fall comes and it is dry. Water is shut off and sprinkler systems drained. The turf dies from winter desiccation.

Asphalt jungle

Perhaps the greatest stresses to trees are the vast areas of asphalt, concrete and reflective surfaces of buildings. An urban area has a microclimate much different from a forest or open prairie because of the influence of these artificial surfaces.

Pavement not only tends to increase air temperatures near plants, but also modifies the water penetration and air exchange in a soil. Reduced oxygen exchange into a soil seriously impairs growth of tree roots. As roots die from oxygen starvation, the activity of anaerobic microorganisms increases soil carbon dioxide content. This causes even greater decline of roots.

Most trees perform best when the soil oxygen level is 15% - 20%. In compacted clays, oxygen content may be reduced to levels below 5%. Under new, sealed asphalt and concrete, oxygen exchange may be reduced by 50% of normal.

One has to wonder how trees can survive at all in the asphalt jungle of a city. A close look at most trees in paved areas will show that they are not really at their optimum. If one looks at the annual shoot growth increments, it is usually the case that trees surrounded by pavement or in compacted soil conditions will have decreasing shoot growth each year when compared with similar trees in a less stressful environment.

In other cases, however, reflective heat from buildings and pavement may cause greater than normal shoot growth and delayed hardening-off. Such trees usually suffer from winter injury.

Drought, not cold, our enemy

Drought is a bigger enemy to trees in urban areas than cold injury. This appears to be world-wide in scope. At the First International Urban Tree Symposium in New York in 1983, a general consensus was that regardless of annual rainfall, drought was a dominant stress factor leading to tree decline in cities.

Trees planted in small spaces surrounded by pavement soon outgrow the pavement-free area. Yet, the irrigation systems provided, if present at all, water only a small space near the trunk.

Trees under such conditions often undergo a paradoxical situation. Surface roots develop and extend between the interface of pavement and soil and soon run low on water or even nutrition. The roots that remain in the original planting pit may go deeper, but soon die from oxygen starvation (drowning) because of excess water accumulation in the planting hole.

Thomas Perry, Ph.D., North Carolina University, has studied urban trees across the United States for several years. He has concluded that, on the average, the useful life of trees in urban areas is just seven to eight years. After that, a tree may still survive, but it is starting a gradual decline. Some trees may decline over a period of ten years or more and eventually succumb to one last stress such as a harsh winter, hot summer or invasion of an insect pest.

Air pollution

The effects of air pollutants on plants in urban areas has been the subject of considerable research, particularly in California, New Jersey and Pennsylvania.

Gaseous pollutants are absorbed into active plant tissue, mostly leaves; and particulates are adsorbed on leaf surfaces. The amount of injury depends upon many factors: the duration and type of pollutant, the concentration of the chemical, microclimatic conditions and the genetic susceptibility or resistance to the pollutants.

Trees in urban areas such as Denver undoubtedly suffer some degree of stress from air pollutants which predispose them to other stresses. Just how much decline in trees is caused by the direct effects of air pollutants is mostly speculative at the present time. Most measurements of air quality are based upon human tolerances of carbon monoxide, ozone, nitrous oxides and sulfur dioxide. Translating these values to plant sen-

sitivity is difficult.

Long periods of exposure to low levels of air pollutants may result in chronic injuries to trees, shrubs and garden flowers that are difficult to distinguish from other causes of poor growth. For instance, in pines, particularly ponderosa, tip browning of older needles is common throughout metro Denver. This injury is very similar to the tip burn from several gaseous pollutants including sulfur dioxide, fluorides and ozone. Studies have shown, however, that the injury is mostly due to high salts in the soil — called chloride toxicity.

A major road block in trying to pinpoint plant maladies on air pollutants is that expensive monitoring equipment is needed. Some cities have attempted using indicator plants such as white petunias, tobacco *(Nicotiana)* and gladiolus since they are very sensitive to specific air pollutants. Such monitoring programs are useful in very localized situations but require trained observers.

Even street lights can cause stress

Trees in well-lighted areas may be influenced by certain forms of night lighting. Studies by Mark Cathey, Ph.D., USDA, and others have shown that some species of trees may suffer stresses if relatively close to sodium vapor lights (the pinkish lights used in many areas). The stress is caused by delaying the normal dormancy of shoots thus subjecting the growth to freeze injury. Where it occurs, it is often only on a branch or two nearest the lights, not the entire tree.

There is some evidence that cytospora canker in cottonwoods growing near sodium vapor lights was more severe following the early freeze in the fall of 1985. It was observed that branches near lights suffered more dieback and subsequent invasion of the fungus than branches away from the lights. It is thought that the lights delayed dormancy of the affected branches making them less cold hardy. The organism then infected the freeze-injured branches.

Avoiding stress to trees

It may not be possible to prevent all stresses to trees, but many preventive measures are available with some good planning and care.

Plant ecologically

Before planting new trees, learn as much as you can about their ecological requirements. If using natives, you can learn quite a bit by just observing where a given species grows and what the surroundings are like. For instance, Colorado spruce will be found in moist, but not boggy sites, and do best in rich, cool soils. It is better, therefore, to plant such trees in a home site on a north or northeast exposure rather than south or west. Pines, on the other hand, perform best in sunny, rather dry and well-drained sites.

Aspen, now becoming a common tree for cities, does best in moist, cool soils and will suffer considerable stress in hot, dry locations.

No tree "prefers" our common heavy clay soils so anything that can be done using organic materials to improve at least the top 9 inches of soil will go a long way in reducing future stresses.

Avoid killing with kindness

A common ailment of trees in cities is the constant attention they are given that is unwarranted and often damaging. Most of us gauge watering by how green the lawn is. This usually results in overwatering, at least shallowly, any trees in the area. Where possible, plant trees and lawns in separate areas and zone the water accordingly.

Most trees are pruned too often and too severely. Much of this is the result of poor selection or poor placement. Some people seem to prune merely for exercise! Before planting, know just how big the tree will get. Anticipate interfering structures and overhead wires. Severely pruned trees undergo stresses that often lead to fatal canker diseases and internal decay.

Fertilizing trees too often or with po-

tent formulations used on lawns can stress trees. While everyone wants trees to grow fast enough to be enjoyed in his lifetime, there is such a thing as too fast. Trees forced into soft growth become stressed at times of high temperatures, may be more brittle in storms and more subject to early freezes.

Herbicides used to control weeds in lawns can be injurious, if not fatal, to trees. It is best to avoid the "weed 'n feed" type fertilizers in lawn areas where tree roots extend — this is most lawns. Spot treatment makes much more sense, is less costly and less likely to injure trees.

Fall watering, especially if conditions are very dry, is essential for survival of trees. There are even periodic dry periods in winter when lack of snow and dry conditions warrant watering. Pay particular attention to south and west exposures. The dieback and loss of many European weeping birches in the area is largely due to winter desiccation followed with bronze birch borer as a secondary problem.

Urban tree stress is an on-going and complex thing. Since no single cause, but rather the complexities of several causes lead to decline, no single solution to the problem is possible. Seek help in identifying stresses to your trees through your county Cooperative Extension office of Colorado State University, city forester or local garden center.

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Insects on Plants: Friends or Foes?

by Boyce Drummond

Anyone who has ever tried to coax vegetables to grow in a backyard garden or tended foliage plants in a living room window knows that insects can be troublesome pests. Mealybugs, plant lice, whiteflies, cabbage loopers, cutworms, and ants all seem to conspire against the efforts of gardeners with even the greenest of thumbs.

And how many of us, while driving through the Colorado countryside, have failed to notice the effects of insects on our forests? For example, tent-caterpillars (moths in the genus *Malacosoma,* family Lasiocampidae) are conspicuous in the spring after they have fashioned their silken homes at the tips of branches of *Ribes* (currant) bushes and other plants. In summer, entire hillsides that were once a rich green may appear as a conspicuous but depressing grey, the color of rotting leaves beneath a melting snow in spring. There are stands of Douglas-fir trees *(Pseudotsuga menziesii)* that have suffered plagues of western spruce budworm *(Choristoneura occidentalis)* for too many years.

I could continue this litany of assaults of insects on plants for several pages, but it would only remind us of what we already know — that insects depend on plants for food and shelter and that sometimes this dependence can weaken or kill those plants that humans would rather see healthy and prosperous — and would divert our attentions away from the many beneficial relationships insects have with plants.

Besides, the majority of plants we encounter out-of-doors in Colorado seem to show little if any insect damage. This is remarkable when we realize that the number of insect species in the state exceeds the number of plant species by at least 10 to 1; a comparison of the numbers of individuals of insects and plants increases this ratio by several orders of magnitude. With plants so overwhelmingly outnumbered, one wonders why there is any intact vegetation left at all, especially considering that we haven't yet mentioned the more conspicuous herbivores, mammals like deer, elk, mice, and voles.

Part of the reason, of course, is that vegetation is a renewable resource. New stems and leaves grow to replace those that are eaten. Another reason is that insects have natural enemies, predators and parasites, that keep their populations in check. In fact, many insects themselves are predaceous or parasitic and do not eat plant material at all.

And yet, those extensive stands of dead and dying fir trees are persuasive testimony to the destructive power of rapidly growing and unchecked populations of herbivorous insects. It is unlikely, however, that all Douglas-fir

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forests will succumb to the ravages of spruce budworm outbreaks. Eventually, the large populations of budworms will support increasing populations of parasites and predators that will reduce the budworm's population to pre-outbreak levels. Twenty-eight species of parasitoids (parasites of larvae and pupae that eventually kill their host) have been reared from western spruce budworm in Colorado (McKnight 1974). Outbreaks were recorded in Colorado in the early 1940s and the late 1950s (McKnight 1971) and each subsided for several years before the next outbreak occurred, the latest beginning in the early 1980s. It is likely that cycles of budworm abundance and scarcity have been going on for centuries.

The world is not all green to herbivores

The mass of green foliage that appears to us to be a vast food supply for insects and other herbivores may look very different from the insect's point of view. After all, plants have been chewed on for millions of years, and natural selection acting on plants has fine-tuned their abilities to curb the appetites of herbivores. Many plants produce chemicals that taste bitter or are poisonous. When first discovered, these chemicals were called secondary plant compounds because they were not essential to plant metabolism and photosynthesis, and botanists could think of no useful function for them. We now know that these chemicals, such as alkaloids, glycosides and saponins, function to protect plants from would-be herbivores.

Ecologists recognize two strategies of chemical defense in plants, depending on whether the plant species is easily found by herbivores (apparent plants) or whether the plant species escapes its enemies in space and time and is thus not easily found (unapparent plants) (Gilbert 1979). Unapparent plants are mostly annuals and include many opportunistic or "weedy" species that colonize new habitats after a disturbance (river edges, roadsides, treefalls, etc.).

By producing a potent poisonous compound, like the cardiac glycosides produced by milkweeds (Asclepiadaceae), an unapparent plant can protect itself from most of the insects (and many of the mammals) that might come in contact with it. The only insects that feed on such well-protected plants are those whose digestive systems have evolved to detoxify or circumvent the poisons. In the case of milkweeds, larvae of the monarch butterfly *(Danaus plexippus)* and larvae and adults of the swamp milkweed leaf beetle *(Labidomera clivicollis)* are such specialists. In fact, the very compounds in milkweeds that repel most herbivores actually serve as stimuli for oviposition (egg-laying) by adult monarchs, helping them to locate these otherwise widely scattered and thus "unapparent" plants.

Apparent plants, which include most trees and other perennial woody plants, are "bound-to-be found" because of their larger size and predictable location from year to year. Producing secondary plant compounds is not a very effective defense, partly because of the huge quantities required for a large plant, and partly because the specialist insects that are immune to the poisons could find the plants so easily. Apparent plants, then, have evolved a quantitative line of defense, producing substances whose increasing concentrations reduce their digestibility to herbivores. For example, oak trees manufacture tannins, which combine with proteins to produce virtually indigestible complexes that are very costly to herbivores to metabolize, thereby greatly slowing the herbivores' growth rate. For generalist herbivores feeding on "apparent" plants, these slower growth rates are compensated by a larger, more constant resource base.

In addition to chemical defenses, plants employ a vast array of mechanical devices to deter herbivores. These include spines, prickles, dense layers of hairs and other pubescence, leaf toughness, deciduousness in response to feeding damage,

and production of resins, latex, and other gummy substances. But insects can breach these mechanical barriers by evolving counteradaptations similar to those that permit feeding on chemically protected tissues.

Milkweeds, as their name implies, are lactiferous (latex producing) and those same leaf-chewing specialists — monarch butterflies and swamp milkweed leaf beetles — that can detoxify the cardiac glycosides in milkweeds, have also evolved behaviors to circumvent the feeding deterrent qualities of the latex released when a leaf is damaged. Before feeding on the edge of a milkweed leaf, these insects first bite through a leaf vein near the midrib. This releases latex at the bite, but in so doing prevents the latex from reaching the area distal to the bite where the insect goes to feed (Dussourd and Eisner 1987). (Figure 1.)

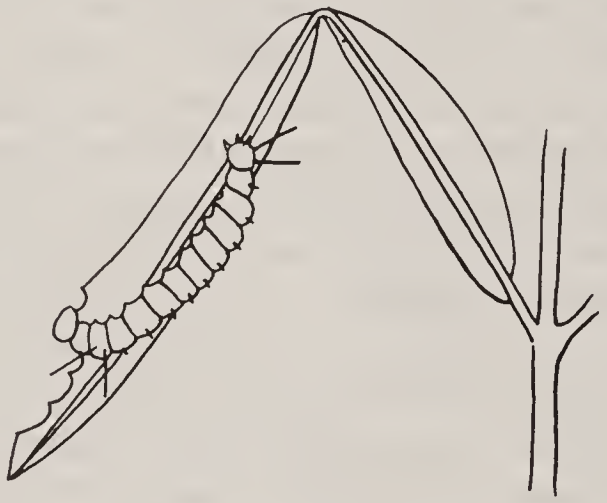

Figure 1. Monarch butterfly caterpillar feeding on milkweed leaf after biting through the midrib to prevent latex flow.

Coevolution

And so it goes, an evolutionary arms race between plants and their herbivores. Plants evolve new mechanical and chemical defenses that, in turn, spur the evolution of modified mouthparts, digestive enzymes, or behaviors in herbivores to overcome them. These reciprocal evolutionary responses between plants and their herbivores constitute a process that has been called "coevolution" (Ehrlich and Raven 1964). Many evolutionary biologists think that coevolution is responsible for generating much of the great diversity that exists today in the plant kingdom and the insect class.

But coevolution is not restricted just to herbivory, which is basically an antagonistic interaction. The coevolutionary process has also produced remarkable cases of cooperation between plants and insects. These partnerships, called mutualisms, benefit both groups.

Insects as pollinators

The most important type of cooperation between plants and insects is pollination, in which plants trade food for sex. It is an evolutionary barter that has profited both groups to an enormous degree. But in terms of natural selection, pollination of flowers by insects is an economic tug of war. Plants reward (with nectar or pollen) animals that assist (by pollen transfer) their sexual reproduction. Natural selection acting on flowering plants "seeks" to maximize the efficiency of pollen transfer (by encouraging pollinator visitation and between-flower movement) and, at the same time, minimize the energy expenditures (in floral displays, nectar, and pollen) that encourage the visitation of animals.

On the other hand, natural selection acting on pollinators seeks to maximize rates of energy intake (uptake of nectar and/or pollen per unit time) and, at the same time, seeks to minimize energy expenditure (movement between plants, number of flowers visited, etc.). The longer such opposing selective forces have operated on a plant/pollinator system, the more we (as observers) are likely to see behavioral, morphological, and physiological adaptations on the part of both populations (i.e., a high degree of coevolution).

The first angiosperms had perfect flowers that produced no nectar. The first insects to visit them (probably beetles) did so to feed on pollen grains exposed during anthesis. Plants with copious and sticky

pollen were favored by natural selection, both because enough pollen was produced to permit some grains to survive beetle feeding and because the sticky grains adhered to the beetles' bodies and were thus carried to the next flower visited. Beetles are clumsy pollinators and their smooth bodies are not well-designed for pollen adhesion and transfer.

The next step was the evolution of floral nectaries, specialized glands that secrete a sugary nectar that rewarded insects visiting the flower with a high energy food. To advertise the presence of the nectar, flowers evolved bright colors and patterns. Insects, meanwhile, evolved a sensitivity to color and pattern that allowed them to recognize these floral signals. Different insect groups evolved different responses to colors. Bees, for example, are highly attracted to blue and purple; butterflies respond primarily to yellows and reds; moths, which are active at dusk and at night, seek out white flowers. (Figure 2.)

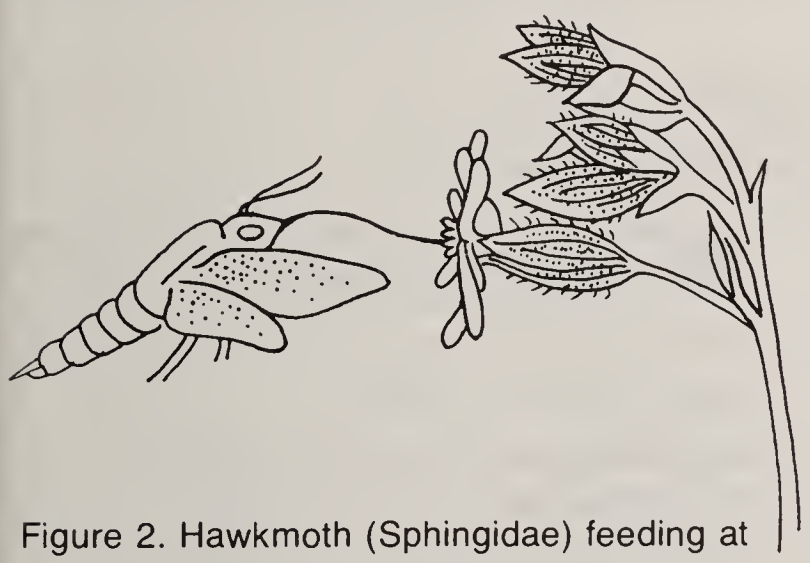

Figure 2. Hawkmoth (Sphingidae) feeding at dusk on white campion flowers.

Because butterflies and bees are shaped differently, so are the flowers they visit. Butterfly and moth flowers tend to have a deep corolla tube with a pool of nectar at the bottom. (Figure 3.) Such a floral architecture effectively excludes beetles, flies, and bees, which have a relatively short proboscis, while favoring the long proboscises of moths and butterflies. Likewise, bumblebee flowers usually enclose the nectar and pollen within a bilaterally symmetrical blossom that must be forced open to gain entry. Golden banner *(Thermopsis divaricarpa)* and other members of the pea family are good examples. By contrast, beetle-pollinated flowers rarely produce nectar. Their blossoms are usually saucer shaped to expose the stamens, with their copious pollen, to the movements of the beetles, which crawl over the flower in what is often called "mess and soil" pollination. There are, however, exceptions, almost all of them interesting, that serve to remind us not to be seduced by the comfort of generalities. For example, the nutmeg of commerce *(Myristica fragrans)* is beetle pollinated, but it produces small, urn-shaped blossoms that are inconspicuous, open only at night, and allow entry only into the staminate flowers (Armstrong and Drummond 1986).

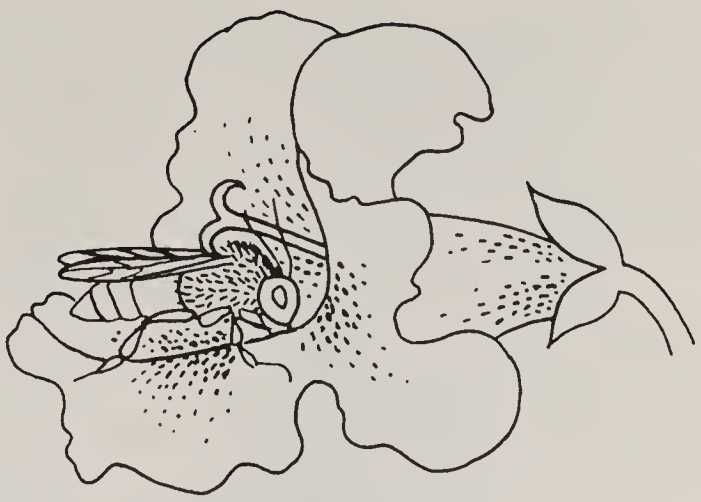

Figure 3. Bumblebee entering flower and contacting reproductive parts with dorsum.

Ecologists classify flowers according to how they function in a pollination system. For instance, "bumblebee flowers" generally display a set of common characteristics designed to attract bumblebees and reward their visits, but that discourage the visits of other insects by making the floral rewards inaccessible. Table 1 summarizes the relevant characteristics of bumblebees and their flowers. (Figure 4.)

Similar tables can be constructed for all pollination classes of flowers, including not only those pollinated by other insects, but also by birds, bats, and even monkeys! An excellent summary of these

Figure 4. Butterfly sipping nectar at small tubular flower.

pollination classes can be found in *The Principles of Pollination Ecology* (Faegri and van der Pijl 1979). Another useful reference is the beautifully illustrated and well-written volume *Insects and Flowers: The Biology of a Partnership* (Barth 1985). Even more rewarding is time spent outdoors watching visitors to flowers and observing their behavior. Couple this with the careful dissection of these same flowers and you will be surprised at how much you can learn about pollination biology on your own.

Ants as mercenaries

Another category of coevolution between plants and insects involves the defense of plant tissue by patrolling insects, usually ants. Some plants attract aggressive ants by providing shelter and food; in return, the ants attack any insect or other animal that comes in contact with the plant. In effect, plants are enlisting ants as mercenaries to help them in their battle against herbivores. An excellent example of this is the mutualistic association between ants and swollen-thorn acacias of Central America.

Ants of the species *Pseudomyrmex ferruginea* colonize a bull's horn acacia *(Acacia cornigera)* as follows. A queen ant bores a hole in the base of one of the enlarged horn-shaped thorns and cleans

Table 1. Characteristics of Bumblebee Flowers and Their Pollinators.

Bee-Pollinated Flowers	Bumblebee Pollinators
1. Odor fresh, not very strong	1. Respond to odors as a close-range, secondary guide, following visual attraction
2. Colors lively, generally yellow or blue	2. Excellent vision; can perceive yellow, blue-green, blue, and ultraviolet
3. Blossom zygomorphic; great depth effect; frequently intricate; semi-closed	3. Bees and higher insects well adapted to complicated flowers because of their size, strength, and intelligence. Other insects rarely able to use these flowers
4. Mechanically strong; good landing facilities	4. Visit begins with land and securing a good foothold
5. Nectar hidden, but not deeply; moderate nectar production	5. Adults use nectar and collect pollen for their broods
6. Nectar guides present, may be ultraviolet	6. Respond well to patterns; ability to see in ultraviolet range of electromagnetic spectrum
7. Sexual organs concealed; stamens few; many ovules per ovary	7. Very efficient pollinators, especially due to their floral constancy; excellent guidance systems and communication; use polarized light for orientation

out the soft pithy center, leaving a hollow shell with a tough woody exterior. In this thorn she lays eggs and rears her broods of worker ants, which can reach over a thousand individuals within a year. As the colony expands, additional thorns are hollowed out to shelter the workers. In addition to producing swollen thorns for shelter, the acacia feeds the ants with exudates from nectaries at the base of its leaves, and with protein-rich nodules, called Beltian bodies, produced at the tips of some leaflets. (Figure 5.)

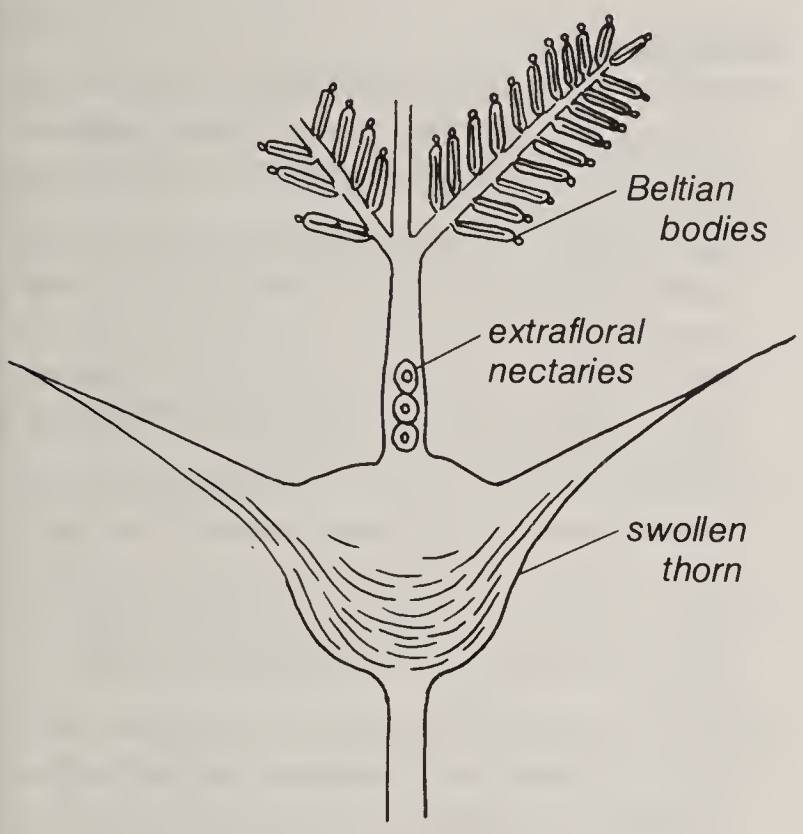

Figure 5. Bull's horn *Acacia* showing adaptations for housing and feeding ants.

Daniel Janzen (1966, 1967) has proved that this is an obligate mutualistic relationship, meaning that neither the ant nor the ant-acacia can survive without the other. In an elegant series of experiments, Janzen showed that swollen-thorn acacias deprived of their ant colonies grew more slowly and survived less frequently than did their counterparts with ant colonies left intact. Unprotected plants were attacked heavily by herbivorous insects. Interestingly, species of acacia that do not rely on ant protection usually contain toxic secondary plant compounds in their leaves.

As in many highly coevolved systems, the ant-acacia mutualism has resulted in some interesting adaptations on the part of both parties to insure the success of the relationship. For example, the ants are active 24 hours a day, with approximately a quarter of the ants patrolling the plant at any one time. Activity around the clock is an unusual trait for ants, but it confers continuous protection for the plant. In a similar adaptive compromise, the ant-acacia produces leaves throughout the year, whereas most acacias lose all their leaves during the dry season. Continuous leaf production insures that the ants are supplied with food throughout the year. Both of these adaptive compromises are essential to the success of the partnership.

Insects as seed dispersers

The feeding of ants by plants has led to another kind of mutualistic association between the two — ant-mediated seed dispersal, an infrequent but fascinating phenomenon. Certain plants, for example, the sedge, *Carex pedunculata,* in eastern United States, produce myrmecochores, oily seeds modified to attract and be spread by ants. The perigynium (the closed, saccate bract surrounding an achene) of *C. pedunculata* includes an expanded base or elaiosome (oil body). The achene and elaiosome together form a dispersal unit called a diaspore. Ants of the species *Aphaenogaster rudis* collect the diaspores and carry them to their nest, where they eat the elaiosomes, carry their larve to the elaiosomes to feed, and deposit diaspores whose elaiosomes have been eaten with other nest debris. The achenes then germinate and the seedlings grow in a soil enriched by the accumulated debris (fecal matter, dead ants, larval and pupal skins, etc.) of the ant nest. (Figure 6.)

In a series of greenhouse experiments, Steven Handel (1976) showed that seedling growth is greatly inhibited if a diaspore remains near the parent plant and other seedlings, with which it must compete. By contrast, seedling growth in anthill debris was strong. Handel's field

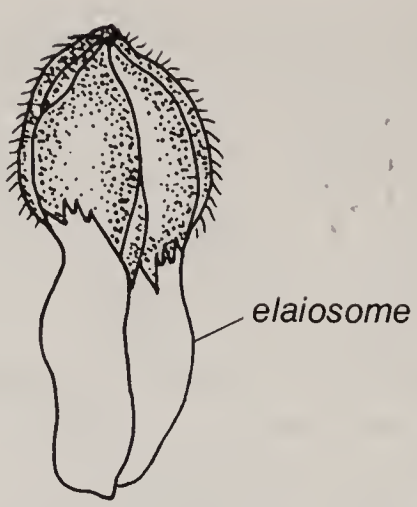

Figure 6. Diaspore of *Carex pedunculata*.

studies showed that successful regeneration of *Carex pedunculata* occurred most often in rotting logs on the forest floor, the sites of ant nests. He concluded that ant nesting behavior was an important component of this plant's population distribution. Because *C. pedunculata* is self-compatible, even widely dispersed, single seeds can start successful new populations.

Unlike the ant-acacia mutualism, however, ant-dispersal of *C. pedunculata* and most other myrmecochore species is not obligatory but facultative, meaning that, although the relationship is beneficial to both, each species can exist independently as well.

Botanists as ecologists

We live in an age of increasing specialization, a situation forced on us by the avalanche of knowledge generated daily. If we are interested in plants we are called botanists. If we are interested in birds, we are called ornithologists (or worse!). And so on. And yet, how much richer is our enjoyment of our favorite organisms if we shed these labels for a broader view that focuses on their interrelationships with other members of the ecological community.

Taken together, plants and insects constitute over half of all organisms known to science. It is exciting to realize that part of this diversity was generated by the incredibly complex and fascinating relationships between members of the two groups. In this context it seems remarkably short-sighted to ignore one group when studying the other. So, if you consider yourself to be a botanist, put yourself in a proper ecological context the next time you go into the field. Try not to think of insects as pests; instead, think of them as dynamic partners in one of the most fascinating *pas de deux* in nature's evolutionary ballet.

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Spring on Your Windowsill: Forcing Bulbs

by Patricia Pachuta

Making spring bulbs bloom by other than naturally occurring conditions is called "forcing." Although this term implies the use of strength or duress, the process, at least when applied to bulbs, is actually more like quiet deception. The bulbs are "fooled" into bloom by an early, simulated winter and a gradual false spring provided by the grower. Forcing bulbs is easily accomplished and even beginners will be rewarded by colorful, fragrant blossoms that will brighten the dreary, snow-filled days of winter.

Bulbs and corms are modified stems from which plants grow. Slice a true bulb, such as an onion, from top to bottom, and a small, undeveloped shoot covered by many layers of fleshy scales is revealed. These scales nourish the growing plant until the new leaves are large enough to manufacture their own food. New bulbs, called bulblets, develop from the base of the bulb. Hyacinths, tulips and daffodils are all true bulbs.

Corms, on the other hand, are solid masses of storage tissue with one or more buds on top. Roots grow from the base of the corm and the corm shrivels as the new plant develops. After flowering, small corms called cormels form on the roots. Crocuses are examples of corms.

However interesting, the botanical distinction between bulbs and corms has no bearing on the forcing process and the term "bulbs" is used in a general way throughout this article.

The steps involved in forcing are simple and straightforward but they must be followed carefully for good results.

The right choices

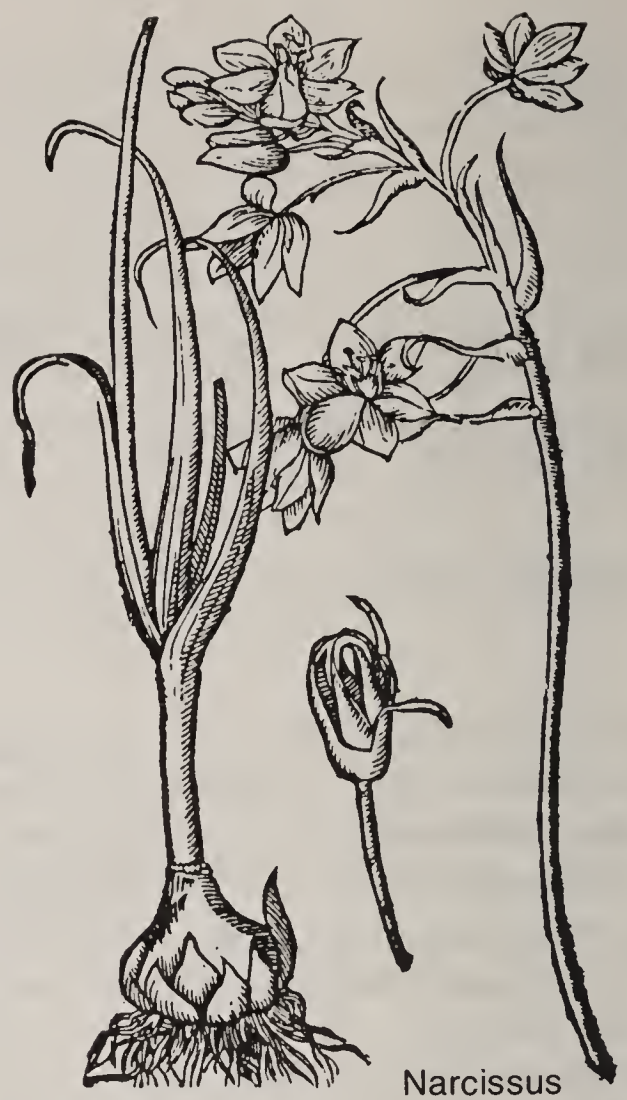
Select proper cultivars for the appro-

Hyacinth

Patricia Pachuta, education director at Denver Botanic Gardens, teaches a yearly class on forcing bulbs. The drawings are from Pier Andrea Mattioli's *Commentarii In Sex Libros Dioscoridis De Medica Materia,* an herbal published in 1569. This volume is located in the Waring Rare Book Room, Helen Fowler Library, DBG.

priate blooming period and that have proven successful for forcing. Suitable varieties of tulips, daffodils, hyacinths and crocuses are all available. In addition, consider some of the smaller and less expensive "minor bulbs" such as snowdrops and dwarf irises. Read descriptions in catalogs and on the bulb boxes. The table that follows may prove helpful as well.

Bulbs are grouped into early, mid-season and late-season bloomers. For an indoor succession of flowers the earliest outdoor bloomers should be selected for flowers indoors in January; mid-season bulbs will bloom indoors from mid-February through mid-March; and late-season bulbs are appropriate for later flowers. These times are approximate and reflect the internal "programming" of the bulb. You will be disappointed if you expect a display of tall, late-flowering bulbs early in the winter just as small, early tulips will not hold well later in the season.


Narcissus

Proper planting

The bulbs must be properly planted. Since they may be held in cold storage longer than their rooting period, it makes sense to pot all the different selections at one time. A suitable potting mixture consists of one part packaged potting soil, one part peat and one part sand. Use clean pots with drainage holes. Shallow pots are traditionally preferred for better effect, particularly with shorter varieties. New clay pots should be soaked overnight so moisture is not drawn from the potting medium.

For uniform bloom plant only one variety per pot. Individual hyacinths are planted in 4- or 5-inch pots, or try three or four of them in a 7-inch pot. Six tulips or two or three daffodils look good in a 6-inch pot. Space all bulbs so they are just touching.

Cover the drainage hole with a small scrap of newspaper or a clay shard to prevent the potting soil from sifting out. After placing several inches of soil in the pots, gently place the bulbs on top. Avoid hard pressure because compacted soil may hinder good root development. Add enough potting soil so that the tops or "necks" of the bulbs barely protrude above the soil. As with all potting projects, be sure to leave a space about three-quarters of the depth of the rim at the top of the pot for proper watering.

At this point students are generally relieved when someone courageously asks how to position the bulbs: The pointed ends go upward. Notice also that tulip bulbs have a rounded side and a flat side. Place them with the flat side facing the outside of the pot. This causes the first leaf of the plant to face outward for a prettier, more uniform result.

Remember to label them with the date, the name of the cultivar and their approximate time of flowering. Water the potted bulbs thoroughly until excess moisture flows from the drainage hole to ensure that the entire soil ball has been watered. Thereafter, check frequently, at least once a week, and keep the soil moist but not waterlogged for good root development.

Simulate winter

The potted bulbs are given an artificial winter period of darkness with temperature of about 35°-48°F. This can be accomplished through the use of a cold frame, unheated cellar or garage or even an extra refrigerator. During this cold period the roots so necessary for good blooms develop.

The old-fashioned way of providing the cold period is to place the potted bulbs in a trench or hole about 15-18 inches deep with a 1- or 2-inch layer of pebbles or gravel in the bottom for drainage. Cover them with a few inches of sand or peat moss to make the pots easier to dig up later; then replace the soil and mulch the top with straw or leaves. Mice and other hungry rodents can be discouraged by placing a fine wire mesh over the top of the pots. During the dry periods that frequently occur in Colorado winters, it will be necessary to water them.

It is far easier, however, to use an unheated cellar, garage or crawl space. If you have the space, a refrigerator is especially convenient. This cold period lasts at least 10 to 12 weeks.

A word of warning: Do not be tempted into bringing the bulbs into your home or greenhouse before the minimum rooting period has passed. Your investment in bulbs would undoubtedly be wasted since flowering is very unlikely.

Spring warm-up

The well-rooted bulbs are brought out of the cold and into warmer conditions to flower, a process that takes about three weeks. By this time, pale yellowish-green shoots will have developed. A location with dim light and about 55°F is ideal at first. Continue to keep well-watered and move to a brighter site still out of direct sunlight after the shoots have greened.

For a steady succession of bloom bring in a few pots every seven to ten days. A cool location will prolong the life of the flowers, so consider placing them in a chillier location especially at night. Although it is impossible to force the same bulbs again, you may want to save them for your outdoor garden. After the flowers have faded, remove the flowering stalks and keep watered until the leaves have withered; then plant outside. The bulbs may not bloom the first year but in subsequent years they should perform well.

Paperwhites

Because they are native to warmer regions than the hardy bulbs already discussed, paperwhite narcissus are among the easiest of all bulbs to force. Instead of a cold period, a cool period of approximately two weeks in a dark spot with temperatures at about 45° to 60°F will result in good root production. Instead of potting them in soil, many gardeners prefer to grow them in shallow decorative bowls filled with gravel or small pebbles and water.

Position the paperwhites so that a third of the bulb is covered by pebbles and add water just to the base of the bulbs. After the rooting period, gradually move to brighter light and in about three to five weeks intensely fragrant flowers will appear. Don't bother saving used paper-

Crocus

white bulbs. They are not hardy in our climate and will not force again.

By keeping in mind a few simple guidelines success with forced bulbs is almost guaranteed. Home gardeners should select proper cultivars suitable for forcing. Bulbs should be potted in clean pots in a well-drained medium. A cold, dark period of 10 to 12 weeks is given to encourage good root development. Finally, the well-rooted bulbs are gradually given warmer temperatures with brighter light to encourage flowering.

Apartment dwellers who are unable to provide a proper place for the cold rooting period should consider forcing paperwhites. Regardless of the bulbs chosen, plant a few extra pots. A pot of forced bulbs is a cheerful, welcome gift that promises warmer days ahead.

How Bulbs are Forced at Denver Botanic Gardens

The beautiful Lobby Court displays provided throughout late winter are the result of many careful hours of planning, potting and nurturing. Bulbs ordered from Holland in March usually arrive in August. They are kept in a well-ventilated, unrefrigerated location until potting in late fall.

A combination of four parts Sunshine Mix (a commercially prepared soilless medium) and one part perlite has proven very successful; it has good drainage as well as adequate water-retaining abilities.

The potted bulbs are rooted in the cooler located near John C. Mitchell II Hall. A drench of fungicide helps prevent fungal problems associated with the poor air circulation of the cooler.

Six to eight daffodils are planted in an 8-inch bulb pan; three hyacinths fill a 6-inch pot; and five tulip bulbs are potted in an 8-inch "azalea" pot.

 Tulips in the Lobby Court at Denver Botanic Gardens.

Temperatures within the cooler are stringently regulated for optimum root and shoot growth before the final "forcing" in the greenhouse. A 50 percent shade cloth shields excessive bright light to prolong the flowering period. To discourage fungal diseases bulbs are watered in the morning taking care not to dampen the foliage.

Finally, after at least eight weeks, the bulbs are moved to the Lobby Court to cheer our winter-weary visitors. For peak floral display, pots of bulbs are generally rotated every five days.

Michael Green
Gardener Florist II

Suggested Bulbs for Forcing

	Early	*Midseason*	*Late*
Hyacinths	Anna Marie (pink) Bismarck (blue) Jan Bos (red) L'Innocence (white) Madame Krüger (white) Pink Pearl (pink)	Colosseum (white) Delft Blue (blue) Delight (pink) Ostara (blue) Perle Brillante (blue)	Amethyst (violet) Carnegie (white) Marconi (pink) Queen of the Pinks (pink)
Tulips	Bellona (yellow) Christmas Marvel (pink) Ruby Red (red)	Hibernia (white) Olaf (red) Paul Richter (red) Yokohama (yellow)	Couleur Cardinal (red) Ornament (yellow) Peerless Pink (pink) Princess Irene (orange) Yellow Present (yellow)
Daffodils	February Gold	Barrett Browning Carlton Dutch Master Joseph MacLeod	Barrett Browning Dutch Master

Mistletoes of Colorado

by Frank G. Hawksworth

Mistletoes in Colorado? Yes, several grow here, but they are not the leafy kinds prized at Christmas time. The leafy mistletoes do not occur in Colorado and in the Rockies are found only about as far north as Albuquerque. Most of the Christmas mistletoe sold in our stores is the species, *Phoradendron tomentosum,* from Texas, where it is abundant on hackberry and mesquite.

There are six mistletoes in Colorado, all in the family Viscaceae. (These were formerly considered to be in the family Loranthaceae but it is agreed now that mistletoes of the Loranthaceae are tropical and don't occur in the United States.) One species of *Phoradendron,* the genus that includes the leafy mistletoes to the south, and five dwarf mistletoes (genus *Arceuthobium*) are found in the state. All our species occur only on conifers.

Dwarf mistletoes are small (usually 1-5 inches high), leafless plants that grow on branches or stems of pines and other Colorado conifers but not junipers. The root system of the mistletoe occurs within the bark and wood of the host branch or trunk. The most common symptom of affected trees is abnormal, clumpy branches called "witches brooms."

Witches broom on ponderosa pine infected with *Arceuthobium vaginatum.*

Unlike the *Phoradendron* mistletoes, which have fruits that are dispersed by birds, the dwarf mistletoes have a unique built-in seed dispersal mechanism. The seed is borne singly in a berry-like structure that, on maturity (August-September), explodes and hurls the projectile-shaped seed outward and upward at speeds up to 60 miles per hour — the undisputed speed champ of the plant world!

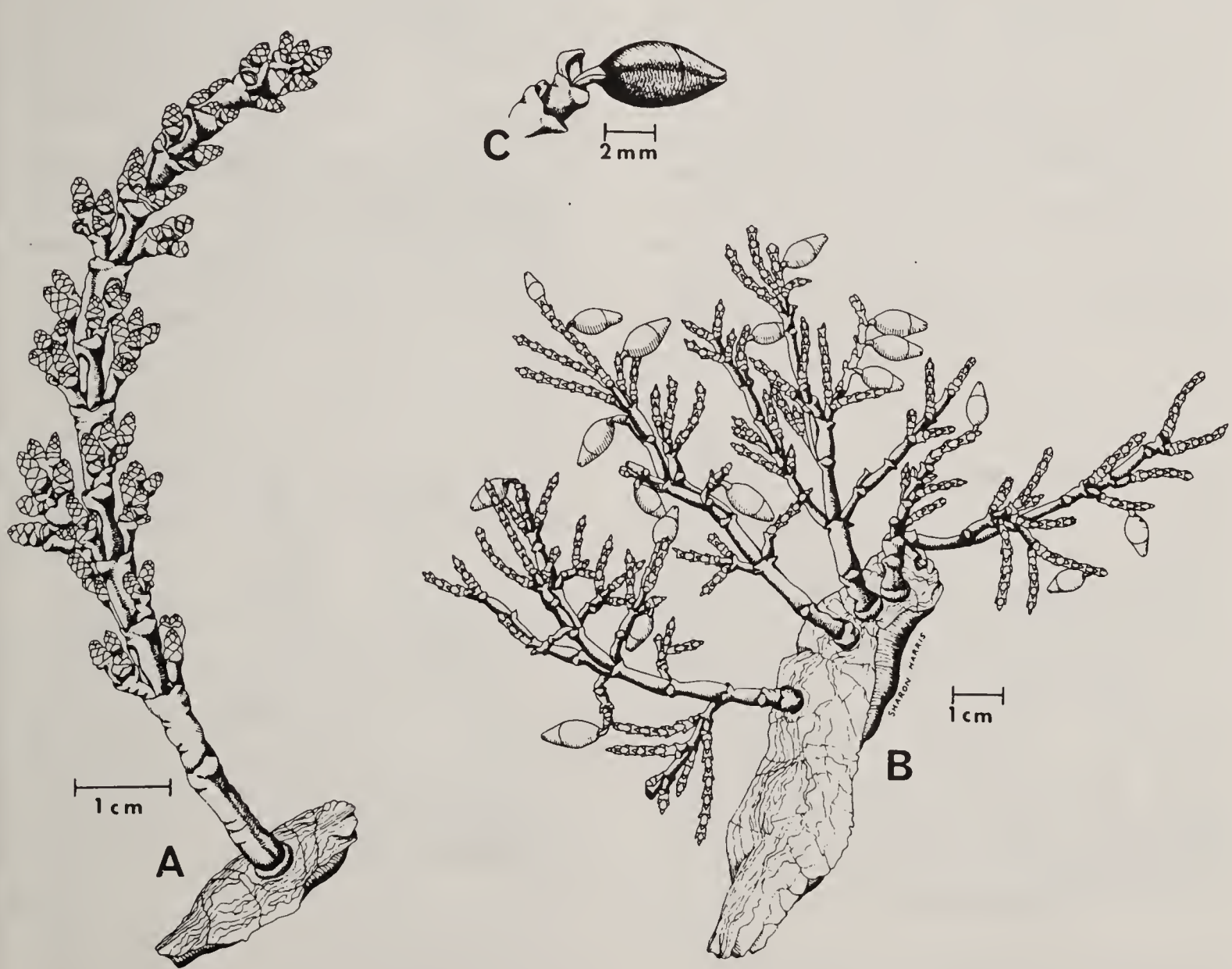
The sticky seeds land mostly on the host's needles and stay there until the first rains, then they are washed down to the twigs and germinate. Initial infection usually takes place in the spring following seed dispersal; after 2-3 years the first small shoots emerge from the host twigs. Fruits do not mature until another 2 years so the dwarf mistletoes have a realtively long life cycle of 5 years or more.

Frank G. Hawksworth, Ph.D., is a research plant pathologist with the United States Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station at Colorado State University.

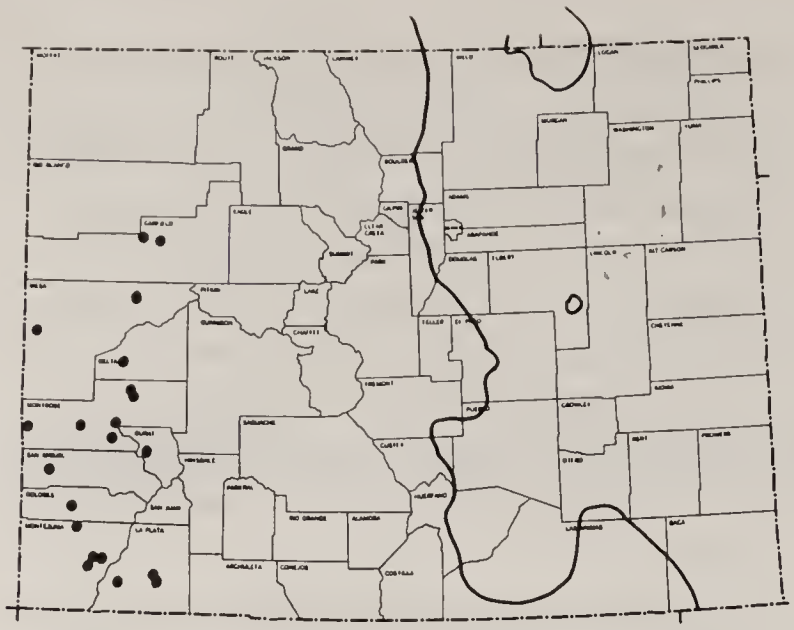
Seed in flight at 60 mph immediately after discharge from fruit.

JUNIPER MISTLETOE *(Phoradendron juniperinum).* This leafless species attacks all kinds of junipers on the West Slope from the Colorado River southward. Common in some localities, for example, near Durango and at Land's End on Grand Mesa, it is not particularly damaging and control is usually not needed. In fact, some homeowners like it as a botanical curiosity in their juniper trees.

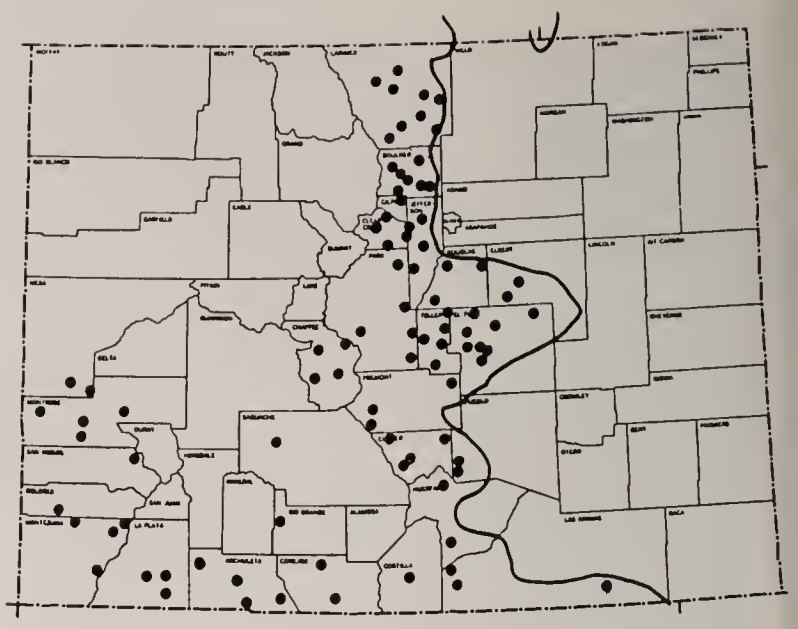
PONDEROSA PINE DWARF MISTLETOE *(Arceuthobium vaginatum).* This common parasite of ponderosa pine, and rarely other pines, occurs throughout southern Colorado and along the Front Range from the New Mexico border north to near Cherokee Park in Roosevelt National Forest. It causes high mortality in several areas, such as in the Sugarloaf area in Boulder County.



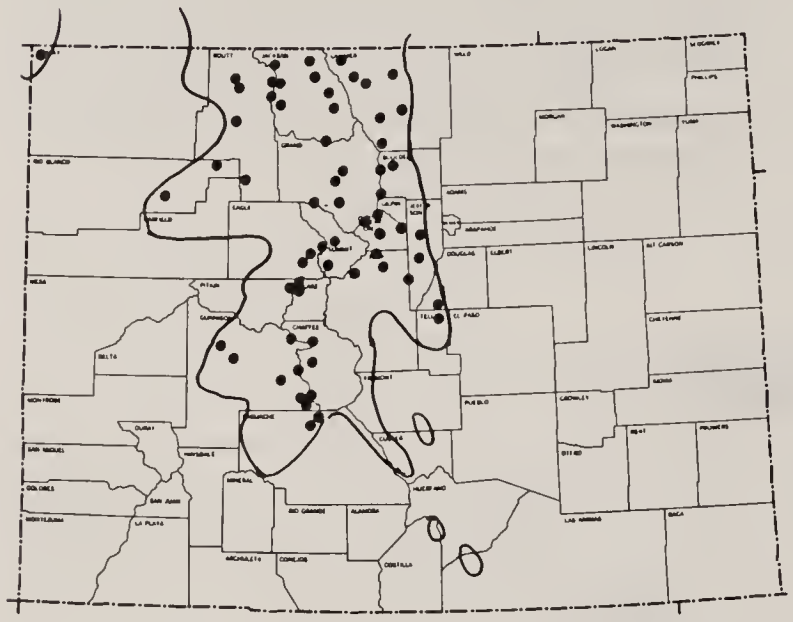
Arceuthobium vaginatum ssp. *cryptopodum* in July: A, Staminate plant; B, Pistillate plants; C, Detail of nearly mature fruit.



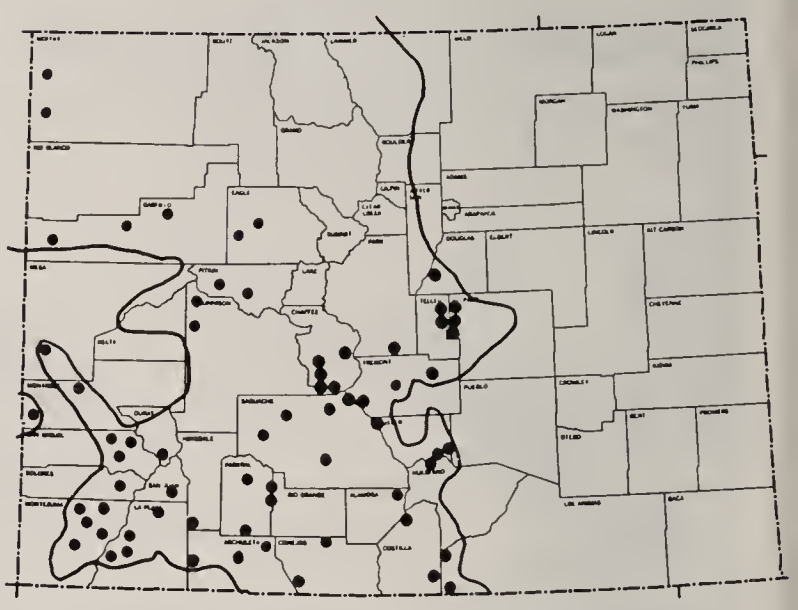
Phoradendron juniperinum on juniper species



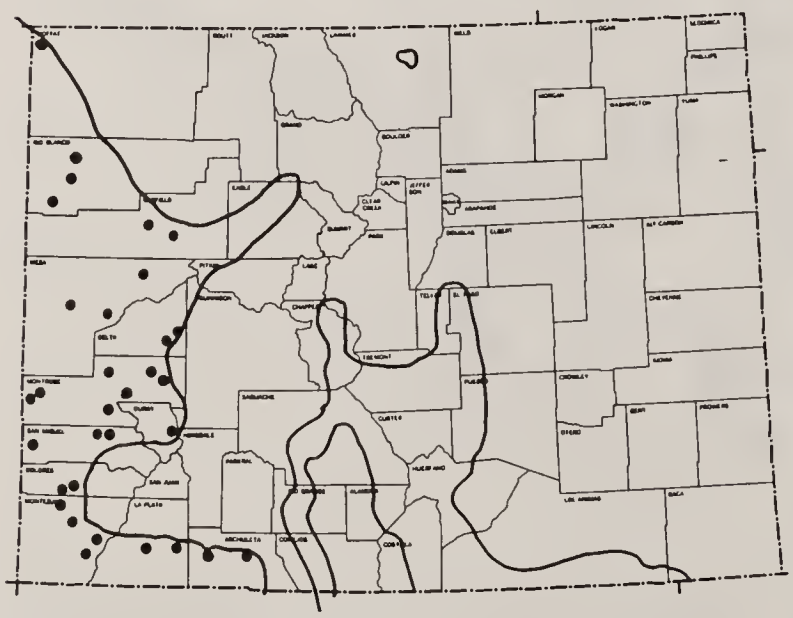
Arceuthobium vaginatum ssp. *cryptopodum* on ponderosa pine



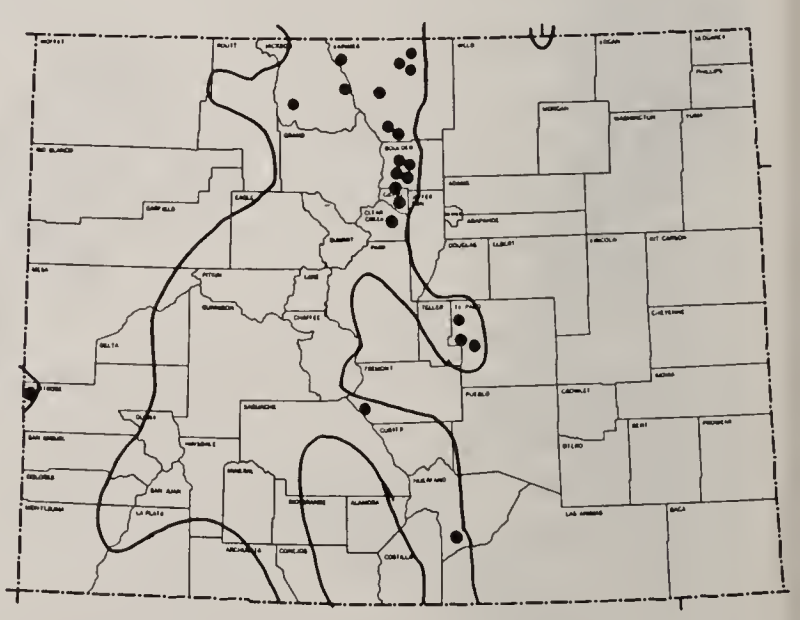
Arceuthobium americanum on lodgepole pine.



Arceuthobium douglasii on Douglas-fir



Arceuthobium divaricatum on pinyon pine



Arceuthobium cyanocarpum on limber pine

 Dots indicate mistletoe collections in Colorado. Solid lines indicate range of host tree.

LODGEPOLE PINE DWARF MISTLETOE *(A. americanum)*. Perhaps the most common mistletoe in Colorado, this species is found in most of our lodgepole pine forests. It ranges from the Wyoming border south to the Rampart Range and along the Continental Divide to near Cochetopa Pass. It hasn't been found in the scattered lodgepole pine stands in the Sangre de Cristo Mountains, Wet Mountains or Spanish Peaks. In northern Colorado it is sometimes found on ponderosa pine, particularly where this tree occurs mixed with infected lodgepole pines.

DOUGLAS-FIR DWARF MISTLETOE *(A. douglasii)*. Our smallest mistletoe, with shoots only about 1 inch high, is essentially restricted to Douglas-fir and is common in the southern half of the state. In the front range, it occurs almost as far north as Sedalia but on the Western Slope it ranges north to Dinosaur National Park. In spite of its small size, it is quite debilitating and lethal to large Douglas-firs.

PINYON DWARF MISTLETOE *(A. divaricatum)*. This species attacks only pinyon pine and is found at scattered locations on the Western Slope where its range extends north of Dinosaur National Park. Although it has not been found in the San Luis Valley, it occurs in nearby New Mexico. It is common in pinyon in some areas, for example, at the main entrance to Mesa Verde National Park.

LIMBER PINE DWARF MISTLETOE *(A. cyanocarpum)*. This uncommon species occurs on limber pine, and rarely on bristlecone pine, in scattered localities along the Front Range from near La Veta Pass to Wyoming. It is quite damaging in the northern parts of Roosevelt National Forest.

Dwarf mistletoes sometimes occur "in captivity" as they are introduced into new areas on transplanted trees. A good example is in the ponderosa pine grove just south of the clubhouse in Willis Case golf course in northwest Denver. The mistletoe was apparently brought in when these trees were transplanted from the foothills more than 50 years ago, and several of them are still infected.

The dwarf mistletoes on lodgepole pine and ponderosa pine are quite abundant: over half of the lodgepole pine and about 20 percent of the ponderosa pine forests in Colorado are affected. These mistletoes cause many kinds of damage: they reduce height and diameter growth of infected trees, increase mortality rates of infected trees, reduce cone and seed production, and increase susceptibility of trees to attack by other pests, such as bark beetles.

Fortunately, dwarf mistletoes can be controlled by direct, non-chemical means. Since spread of these mistletoes is low, pruning in light-to-moderately infected trees, and removal of heavily infected trees, can markedly reduce damage. Branches with mistletoe shoots at least 6 inches from the trunk can be pruned. Generally, trees with mistletoe in the upper half of the crown are too heavily infected to be saved by pruning. These trees should be cut; however, if they are over 40 feet from the trees to be saved, they could be left. This distance is too far for the mistletoe seeds to spread. The only way to treat mistletoe plants on the trunk is to knock off the brittle shoots every couple of years. While this will not stop resprouting of new shoots, it can prevent seed production and spread. Control of dwarf mistletoes by chemicals or biologic agents (insects, fungi) is being investigated, but agents that can be recommended are not yet available.

The nearest Colorado State Forest Service district office can provide advice on evaluating and controlling dwarf mistletoes.

Lady Botanist of Skyland Ranch

Ruth Ashton Nelson

1896-1987

by Jane Ramsey

The brilliant blue sky sparkles as tremendous cumulus clouds billow above two majestic ponderosa pines that stand on a gentle slope where aspens shimmer in a slight breeze. Skyland Ranch, elevation 8500 feet, stretches high above Dry Gulch Road northeast of Estes Park, Colorado. Eagle Rock is in the foreground and the front range of the Rockies, punctuated by Longs Peak, pierces the horizon. Peace and beauty exist here. This was the home of Ruth Ashton Nelson, one of the foremost botanists of the Rocky Mountain region, for more than fifty years.

Ruth Ashton Nelson at Skyland Ranch, May 1986.

Early childhood

Ruth Elizabeth Ashton Nelson, daughter of Grace and Willard Ashton, was born November 29, 1896, in Roxbury, Massachusetts. From her earliest memories she was fond of all flowers and her mother's great love for the outdoor life was a primary influence. The family moved about rather frequently but usually returned to her grandparents' farm on Martha's Vineyard for the summer. The many moves, plus her mother's conviction that nature was a more important teacher than formal schooling, meant that Ruth had only one uninterrupted year of school prior to high school. At that time she attended a small progressive school on Cape Cod. Nevertheless, she entered Mt. Holyoke College, graduated in 1922 with a major in English and had taken as many field courses in botany as the school offered.

The young college graduate was not only interested in flowers; she had decided at an early age that she wanted to live in the West and preferably in the mountains of Colorado. This idea had been in her mind from the time the family first came to Colorado in the summer of 1905. Her paternal grandfather had a department store in a small Illinois town where her father, rather reluctantly, had gone to work. While living there

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Jane Ramsey is a free-lance writer who has been living in Estes Park, Colorado since her retirement ten years ago.

This article is based on an interview with Ruth Nelson at her Skyland Ranch in July 1985.

a promoter interested her father in vacationing at the Boulder/Greeley Colony west of Estes Park on the Big Thompson River near the present road to the YMCA of the Rockies.

The family traveled to Denver by train, stayed overnight, then boarded a local train to Lyons. After lunch in a small restaurant there, they rode in a four-horse stagecoach up the narrow road in North St. Vrain canyon. They were deposited in the village of Estes Park late in the afternoon. Ruth's father rented two small burros from Sam Service who had a general store on Elkhorn Avenue. The children had a fine time with these animals all summer. "One burro was a perfect little animal," said Ruth, "but since my sister was several years younger, she usually rode the good burro and I was left with the stubborn one."

One of the memorable trips that summer was an overnight excursion up Roaring River to Lawn Lake. Two horses were rented, bedrolls and provision tied on their two burros. The Ashtons with Ruth, her sister and three year old brother started off across Horseshoe Park, a ranch where numerous cattle, horses and burros were being grazed. An old cabin at Lawn Lake, which had been built by the men who made the dam some years earlier, offered shelter. "There were only two bunks, but the family took in a young couple who appeared to be lost. Mother and my little brother had one bunk; we two girls shared our bunk with the woman; the men spread out bedrolls on the floor," recalled Ruth.

Ruth's mother was so entranced with the alpine beauty and the myriad wildflowers that she persuaded her husband to stay for a second night. That night they all slept outside beside a trickle of a stream. In the morning they awoke to find the water frozen, but Ruth does not even remember being cold.

During this summer her mother had a fortieth birthday. Usually the family celebrated birthdays with a large cake and candles. Since this was not possible in camp, the children decided to collect 40 different wildflowers to present to their mother. The gift delighted her.

Later, after her parents were separated, Ruth's father returned to the Estes Park area and purchased the Horseshoe Ranch. He built Horseshoe Inn in 1907 or 1908, aided by his brother. Although this was sold in 1915, Mr. Ashton kept the property now known as Little Horseshoe Park. The National Park purchased the building and land in 1933 under a life tenancy which was relinquished upon his death in 1947.

In about 1912 Ruth's mother brought the three children for an unforgettable summer spent at the old hotel at Glen Isle on the north fork of the South Platte River between Denver and Leadville. They had come that far by the Colorado and Southern Railroad, but her mother decided they should travel on over the mountains. She hired an elderly man, two saddle horses and two burros. The small group came up Platte Canyon, camped on the northeast edge of South Park, and continued over the Contental Divide by way of Georgia Pass, through Dillon, and north to Hot Sulphur Springs. They decided to stay at Hot Sulphur Springs where Ruth's mother could take advantage of the medicinal qualities of the springs. There they camped for two months. When autumn arrived the children attended a two-room school until Ruth's father came to visit. He took Ruth with him by train to Denver and on to Ft. Collins where he was then living. Shortly she rejoined her mother who took them to California for a time before returning east.

Married years

Years later after Ruth graduated from Mt. Holyoke College, she headed back to Colorado. She enrolled in Colorado Agricultural College (Colorado State University) in Fort Collins to study for a master's degree in botany. In summers she worked as a naturalist in Rocky Mountain National Park.

While working for the Park, Ruth began to look for land that she could homestead. She hoped to establish a girls' camp. However, no suitable site could be found in the Estes Park area. Finally, with her father's assistance, she purchased 400 acres in 1925

and named it Skyland Ranch. She brought her possessions up a rutted trail by wagon and moved into the original three-room homestead cabin.

Ruth's dream for a girls' camp never came to fruition because something more important intervened. With a quiet smile she explained, "I fell in love with a very wonderful man." In 1930 while she was studying at Colorado Agricultural College, she met Dr. Aven Nelson, President Emeritus of the University of Wyoming, founder of the botany department and herbarium at that school, and noted throughout the west as the authority on the flora of the Rocky Mountain region. The young graduate student sought Dr. Nelson's help with the identity of the plants in Rocky Mountain National Park, the subject of her master's thesis. He recognized in Ruth a genuine similarity of interest. That fall when a graduate opening developed at the Wyoming herbarium, Dr. Nelson offered the position to Ruth. He was soon describing her as "very competent."

Their common interest in botany brought the distinguished professor, a lonely and recently widowed 71-year-old, and the young graduate student together. "His family noticed that Miss Ashton was included for picnics and parties, but no one suspected a match was in the making" (*Aven Nelson of Wyoming* by R.L. Williams). By spring of 1931 they were engaged and on November 20, 1931 (Ruth's thirty-fifth birthday), they were married in the Episcopal Church in Santa Fe. After an initial flurry of surprise and alarm on the part of Dr. Nelson's grown daughters, the newlyweds were happily accepted. His home in Laramie was divided into a duplex so that his widowed daughter, Neva, and her three children could continue to make their home near him. Dr. Nelson, even though he no longer taught, continued to keep in touch with many of his former students who admired him greatly and had gone on to be leaders in the field of botany. He remained as curator of the Rocky Mountain Herbarium and research botanist in taxonomy. Ruth continued as his able assistant.

With material from her thesis and with the encouragement of her husband, Ruth contracted with Rocky Mountain National Park to publish her first book, *Plants of Rocky Mountain National Park*, in 1933. It was so successful that a revised edition was printed in 1953. A third edition in 1970, printed in full color, was the result of much additional study and field work. Dr. Beatrice Willard, then of Thorne Ecological Institute, whom Ruth had first met in 1954 on an alpine trip out of Paris, collaborated with her for the most accurate listing of plants in Rocky Mountain National Park. The latest edition, 1982, is still considered the authoritative guide for persons interested in mountain wildflowers, but untrained in botany. The key to identification also makes it valuable for classroom study, or for the amateur field botanist.

In addition to her work in the herbarium and the publishing of her book, Ruth accompanied her husband on numerous trips. In early 1935 they spent three months on a collecting trip near Tucson. Their work was extensive and rewarding; they returned home with more than a thousand species in a quantity sufficient to make eight to ten sets.

She also went with Dr. Nelson to Corvallis, Oregon where they visited one of his former students who was on the faculty at Oregon State University, and where he spoke to the honorary society, Phi Kappa Phi, of which he was president-general at the time. They continued on to the Fifth Pacific Science Congress in Vancouver and found time to do some collecting in the northwest on their return trip.

On the last day of July 1935 they sailed for Europe with a botanical congress tour which was to convene September 1, in Amsterdam. Among the most interesting of their activities was a visit to the Pasteur Institute in Paris, and a post-conference visit in Norway with descendants of Aven's mother. Perhaps the greatest thrill of the trip was a visit to Uppsala, the old university town north of Stockholm, center of the work of the Swedish botanist and taxonomist, Carolus Linnaeus. Linneaus is considered the founder of the binomial system of nomenclature and the

originator of the modern scientific classification of plants. As president of the Botanical Society of America, Dr. Nelson and his wife met world leaders in their field and visited the famous botanical gardens in England and Germany as honored guests.

In 1937 the Nelsons decided they would like to visit Alaska in order to spend a summer collecting the flora of Denali (Mt. McKinley) National Park. It took two years for the arrangements to be completed. Knowing of Dr. Nelson's reputation as the dean of Rocky Mountain botanists and Ruth's experience with the naturalist program of the park and her well received book, *Plants of Rocky Mountain National Park,* the National Park Service was enthusiastic about the opportunity to have this knowledgeable team catalogue the plants of Denali. In addition, the Park Service thought this research would facilitate its study of the vegetative cover of the Dall sheep range in Denali National Park. The Park Service agreed to give them transportation and lodging; the University of Alaska agreed to pay for a set of the plants, as did the National Park Service, the Rocky Mountain Herbarium in Laramie and the National Herbarium.

When the Nelsons arrived at Seward by boat from Seattle in 1939 there were few roads. They took the railroad inland to Fairbanks and used transportation provided by the government to get them to the Park. They arrived in mid-June and were lodged in a log cabin at headquarters. The superintendent had a car which they were to use, but it soon broke down. After that, they rode horseback into the Park, or used any Park vehicle going out that day . . . dump trucks, pickups, whatever. The only road went to Kantishna, a mining camp, a hundred miles from headquarters. The Nelsons were dropped off at different localities along the way. They spent the day hiking into the back country to collect, then returned to the road to be picked up in the afternoon.

They carried their collected specimens in a vasculum, a tubular metal case used by botanists. Dr. Nelson's case was larger than the standard but the same cylindrical shape with a door that unhooked so that any plants collected could be stored inside. After the couple returned to their cabin, they spent the evening identifying the plants and recording data. Whenever possible they collected more than one individual plant of a species, sometimes as many as 15. The data collected would later go with each plant when it was filed in the herbarium.

The Nelsons left Alaska in late August, sailed from Seward to Seattle, and received their collection by freight a week later. Assembling their collection of some 500 species was a tremendous task. It was particularly difficult to determine these species as there was little in print on the flora of Alaska. However, by March 1941 four complete sets, along with some "stub" sets, were completed. Ruth wrote the formal report and the sets were distributed as promised.

The University of Wyoming Herbarium of Rocky Mountain plants has long been considered one of the finest in the western states and is now housed in a fireproof building named for Dr. Nelson. As Dr. Nelson's health deteriorated and he retired from the University, Ruth applied for and received an appointment as director for the University of Oklahoma Herbarium. She was active in this work from 1944 to 1949.

In 1949, they moved to Colorado Springs where Dr. Nelson died March 31, 1952. Following his death, Ruth continued research and writing and kept in contact with the many renowned botanists she had met with her husband.

Ruth Nelson, Author

A spring vacation to Zion National Park with one of her dear friends, Dee Godesabois, led to Ruth's writing a second book for the National Park Service. Her book, *Plants of Rocky Mountain National Park*, was well known. When she walked into Zion National Park headquarters to visit with the park naturalist, he picked up her Rocky Mountain book from his desk and said, "When are you going to do one of these for us?"

Ruth accepted the challenge and during the following two years spent many months

at Zion living in a cabin near headquarters the first year, later in a park dormitory. The park naturalist was determined that the book should be good looking and insisted upon professional design. As a result *Plants of Zion National Park,* finished in 1976, is a particularly handsome production.

Her third book, published independently by Skyland Publishers in 1969, with succeeding editions in 1977 and 1979, is the *Handbook of Rocky Mountain Plants.* It covers a wider geographic range of the Rocky Mountains than her earlier work as it lists plants from northern Arizona and New Mexico to Canada. Not all species to be found in this region were listed and described, but representative ones were carefully included.

Ruth Ashton Nelson died Saturday, July 4, 1987, at a retirement center in Colorado Springs where she lived after moving from Estes Park, her home since 1964. In her later years, Ruth continued to walk with the sure-footed tread acquired through many years of hiking in the Rocky Mountains in search of flower specimens. Always humble and unassuming, Ruth would only admit that she had led "an interesting life." She was always generous in sharing her botanical knowledge, not only through her books, but in classes and lectures on wildflowers and with her many friends. She was a kind and gentle person.

Friend and fellow botanist, Dr. Beatrice Willard, in the forward to *Plants of Zion National Park,* wrote, "As one who has had the special privilege to walk many trails of Rocky Mountain National Park with Ruth Nelson, I have seen firsthand the close coincidence between the person in real life and the botanist-author that shines through the written page . . . We are all the richer having known Ruth Ashton Nelson — personally and through her writings."

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