Yuccas

OF THE SOUTHWEST

JOHN MILTON WEBBER

AGRICULTURE MONOGRAPH NO. 17

U. S. DEPARTMENT OF AGRICULTURE

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Cytologist
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Bureau of Plant Industry, Soils, and Agricultural Engineering
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YUCCAS OF THE SOUTHWEST[1]

JOHN MILTON WEBBER[2]

Cytologist

Division of Cotton and Other Fiber Crops and Diseases

YUCCAS are among the most valuable plants of the southwestern deserts. Their heads of leaves and their large stems intercept rainfall and reduce its flow, and the rhizomes and long, spreading lateral roots protect the soil from washing or blowing away. The dead yucca leaves, as well as the waste material of animals associated with yuccas, greatly increase the organic content of the soil. This waste material not only enriches the soil but materially increases its water-holding capacity. In many desert areas, each yucca, like many other desert shrubs, gradually improves its immediate surroundings, until a small community of its own is established. This community, consisting of small plants, rodents, insects, and occasionally birds, could not exist without the protection of yucca.

Yuccas provide food, shade, and wind protection for livestock, antelope, deer, birds, and many rodents and other small animals. All grazing animals relish the young succulent leaves, and in many areas the older yucca leaves are almost the only permanent food that cattle have to carry them through the dry season. Although the pungent apex of the leaves discourages grazing, cows learn to chew the leaves from the stem outward and to extract the heart, which is very palatable, of the head of leaves. On overgrazed lands, goats eat the entire heads of leaves. Officials of the New Mexico Cattle Growers' Association stated that large herds of cattle have been maintained for 2 months on ranges where fresh *Yucca elata* leaves supplied fully half the feed and

[1]Submitted for publication May 16, 1952.

[2]The writer is gratefully indebted to the late Prof. Herbert John Webber, formerly of the University of California, for his suggestions, arguments, and assistance in the field and laboratory; and to Dr. Irma E. Webber, collaborator, U. S. Department of Agriculture, for her suggestions and advice in the preparation of this manuscript. The writer is also under obligation to the following research workers for acting as guides during his visits to various sections of the country: Robert H. Peebles, U. S. Department of Agriculture, Sacaton, Ariz.; Kenneth W. Parker, U. S. Department of Agriculture, Tucson, Ariz.; Dr. Carl B. Wolff, Rancho Santa Ana Botanic Garden, Anaheim, Calif.; Orville A. Parsons, U. S. Department of Agriculture, Lamar, Colo.; Dr. A. L. Hershey, New Mexico College of Agriculture and Mechanic Arts, and Albert R. Leding, U. S. Department of Agriculture, State College, N. Mex.; D. R. Burnham, U. S. Department of Agriculture, Tucumcari, N. Mex.; V. L. Cory, Southern Methodist University, Dallas, Tex.; and Quinton A. Hare, U. S. Department of Agriculture, Delta, Utah. Miscellaneous information, seed, and fresh and dried specimens were supplied by the following: D. R. Burnham; R. H. Peebles; V. L. Cory; O. A. Parsons; Dr. L. M. Pultz, University of Arizona, Tucson; Kenneth I. Ross, U. S. Department of the Interior, Mesa Verde National Park, Colo.; Fred Ares, U. S. Department of Agriculture, and Prof. C. W. Botkin, New Mexico College of Agriculture and Mechanic Arts, State College; Charles G. Marshall, U. S. Department of Agriculture, Albuquerque, N. Mex.; Bernell McAllister, U. S. Department of Agriculture, Price, Utah; Prof. Arthur H. Holmgren, Utah State Agricultural College, and Dr. F. W. Lieberman, U. S. Department of Agriculture, Logan, Utah; Dr. Seville Flowers, University of Utah, Salt Lake City; and Leslie N. Goodding, formerly of the U. S. Department of Agriculture.

that in many cases the ranges would suffer as much as 50 percent damage if the yuccas were harvested.

Yucca has been used most extensively for its fiber. The leaves of most species are long and slender and furnish a fiber that is suitable for the manufacture of binder twine and for rope in which great strength is not required. During World War I about 80 million pounds of yucca fiber from leaves collected in New Mexico and Texas was used as a substitute for jute in coarse bagging for covering cotton bales. In World War II large acreages of *Y. glauca* were harvested in New Mexico, shipped east, and made into a special heavy paper for the United States Navy.

The fibrous stems of *Y. brevifolia* and inflorescences of *Y. whipplei* are used in the manufacture of many novelties, such as post cards, scrapbooks, book bindings, napkin rings, window dressings, and lightweight clubs used in play and comedy. At the present time veneered yucca is being widely advertised in southern California for interior wall covering. It is said to act as an insulating material and to improve acoustics, as well as to beautify the walls.

ECOLOGY

Yuccas are distributed over considerable areas in our southwestern plains, valleys, and mountains. They occur near sea level in southern California to 8,000 or more feet elevation in the Rocky Mountains of Colorado. Although in the montane forest the yuccas are usually thinly scattered in exposed areas, they occasionally form small patches. On the lower mountain slopes and bajadas they show a preference for southern and western exposures, and in these regions they usually occur in large belts. Except for *Yucca elata* and *Y. glauca,* the plants of the plains and valleys are thinly scattered or in small, dense patches. *Y. elata* and *Y. glauca* commonly occur in belts, which extend for many miles.

In the mountainous parts of central Colorado, the yuccas are subjected to frequent cloudiness, 20 to 40 inches of precipitation yearly, and moderately to extremely low temperatures. Snow has been recorded every month of the year in several yucca localities, and the plants are frequently covered with 40 or more inches of snow each year. The growing season in these areas is 90 to 140 days. In the mountainous parts of southwestern Colorado and Utah and in northern Arizona and New Mexico the yuccas are exposed to somewhat milder conditions, and in similar regions of southern New Mexico, Arizona, and California and southwestern Texas they are mainly subjected to a desert or semidesert climate.

The yuccas of the valleys and mountain slopes of the deserts and semideserts undergo cloudless, hot days, with very little rainfall and with low humidity. Maximum temperatures of 95° to 120° F. are common in the summer, and winter temperatures rarely fall below 20° F. Although the annual precipitation varies from approximately 5 to 20 inches, very little of the area receives more than 10 inches of rainfall. In southern California the rainfall is mainly limited to the winter months, but in southwestern Texas, New Mexico, and eastern Arizona summer rainfall predominates. The growing season in these desert areas is from 195 to 240 days.

On the Edwards Plateau, west-central Texas, the yuccas are exposed to semiarid conditions. The rainfall is about 25 inches, and the temperatures range from near zero in the winter to 110° F. in the summer. The atmospheric humidity is rather high, and the growing season averages about 230 days.

Southeast of the Edwards Plateau the yuccas are found in a zone of transition from the deserts of the west to the humid areas of the east. West of the Edwards Plateau the desert conditions become increasingly severe, until they reach their maximum in southern Arizona and eastern California. The semi-desert conditions of the Plateau extend north and northwest into the plains of northwestern Texas, southeastern Colorado, and northern New Mexico and Arizona. In the latter sections, however, the rainfall is infrequently distributed and somewhat lower. The yuccas in southeastern Nevada, west-central and eastern Utah, and northwestern Arizona are exposed to rather severe desert conditions, whereas those south and west of the Mojave Desert of California grow in a mild desert climate.

Although yuccas are found in all types of soil, they are more common in sands and gravels. *Y. baileyi, Y. angustissima, Y. constricta,* and especially *Y. elata* and *Y. glauca* are particularly common on the more compact sandy soils. These sands are occasionally red, usually 4 or more feet deep, and frequently underlain with caliche or granite hardpan. The remaining species exhibit a definite preference for a rather coarse-textured gravelly loam. These soils are usually 2 or 3 feet deep and are mainly underlain by a rock bench. The former sandy soils are characteristic of desert grasslands and western prairies, while the latter are commonly associated with desert plains, alluvial fans, and mountain slopes.

Yucca treculeana, Y. torreyi, Y. schidigera, Y. arizonica, Y. brevifolia, Y. whipplei, and *Y. rostrata* are chiefly found on gravelly soils. Although *Y. thompsoniana, Y. rupicola, Y. reverchoni, Y. neomexicana,* and *Y. gilbertiana* are also gravelly soil plants, they frequently occur on rocky ledges and mesas, where the soil is very shallow. On the ledges the plants grow in the gravel-filled fissures of the rock bench. *Y. rupicola* appears to prefer a limestone soil, but many fine plants of *Y. gilbertiana* occur in a rather finely decomposed slate soil. *Y. carnerosana* and, especially, *Y. faxoniana* exhibit a preference for the coarse gravelly and rocky soils of the mountain slopes and mesas, whereas *Y. schottii* mainly occurs in gravelly soils of mountain ravines. Although *Y. baccata* is mainly a woodland, gravelly soil plant, it occasionally extends into the compact sands of the grasslands. In California *Y. whipplei* is rather common in red clay, and in southwestern Texas *Y. torreyi* frequently occurs on a similar, poorly vegetated soil. On the eastern slopes of the Edwards Plateau, Tex., *Y. rupicola* is occasionally found in a calcareous clay, and 6 miles south of Kiowa, Colo., *Y. glauca* occurs in a rather large clay marsh, which appears to be quite saline. The yuccas in the latter area are extremely vigorous, and they do not appear to be suffering from excess moisture or salt. They differ from typical *Y. glauca* in the following characters: The plants are extremely dense, having 33 or more heads of leaves per square meter; the leaves are very glaucous, flexible, and sparsely filiferous; and, although the leaf apex is sharply pointed, the point is flaccid and nonpiercing.

All of the preceding soils, except those in the Kiowa locality, are well drained and have little or no subsurface water. It is a common expression in the desert regions that, "Yuccas do not like to have wet feet." Wolf (*34*)[3] has reported that excess irrigation of *Y. schidigera* caused heart rot. The disease is common in other species of yuccas if they are overirrigated. All species in the writer's nursery, except *Y. rupicola* and possibly *Y. reverchoni,* are more vigorous than native plants. This extra vigor is undoubtedly the

[3] Italic numbers in parentheses refer to Literature Cited, p. 93.

result of an increase in water, coupled to some extent with better and richer soil, and, possibly in a few cases, with a longer growing season. Native plants of *Y. rupicola* are undoubtedly subjected to more rainfall than those in the writer's nursery.

The greatest response to water is that of length of life of the leaves, which is reflected in the size and shape of the heads of leaves. When rainfall is insufficient the outer leaves of the head die, and in severe drought periods only those leaves imbricated around the buds may remain fresh. On the other hand, with sufficient water the leaves remain alive considerably longer than usual and the leaf heads are exceptionally large, or even wanting in cases where the leaves remain fresh along the entire length of the stem. The size of the leaves is probably equally as responsive to variations in supply of water. In the Rancho Santa Ana Botanic Garden, the average length of leaves of unirrigated *Y. schidigera* is 67.5 cm., while that of irrigated plants is 80.1 cm. Although the leaves of the irrigated plants are somewhat broader than those of the unirrigated ones, no measurements have been made. Yuccas with extra large leaves and leaf heads are common in gardens, along roadsides, or in fields where cattle have worn trenches around the bases of the plants.

Undoubtedly stem growth and sprout formation are correlated with leaf size and longevity. In the *Y. schidigera* plants discussed above, the unirrigated plants average 1.62 sprouts per plant and their main stems average 41 cm. tall. The irrigated plants average 3.93 sprouts per plant and their main stems approximately 85 cm. tall. Furthermore, many of the sprouts of the irrigated plants are nearly as tall as the mother shoot, but only a few of the sprouts of the unirrigated plants have developed stems of appreciable length. In these yuccas, the stems of all the irrigated plants are entirely covered with fresh, green leaves, whereas, except for a normal-size apical crown, the stems of the unirrigated plants are covered with dried, reflexed leaves. The writer has found a similar increase in sprouting of semi-irrigated plants of *Y. baccata, Y. torreyi,* and *Y. schottii.*

Yuccas are associated with many vegetational communities and plants. In the desert and plain grasslands they are commonly associated with the following perennial grasses: Blue and hairy grama (*Bouteloua* spp.); three-awn (*Aristida arizonica*); galleta (*Hilaria* spp.), tobosa (*Hilaria mutica*), and curly mesquite (*Hilaria belangeri*); dropseed (*Sporobolus* spp.); and beardgrass (*Andropogon* spp.). The common shrubs of these regions are fourwing and spiny saltbush (*Atriplex* spp.), velvet and honey mesquite (*Prosopis* spp.), rabbitbrush (*Chrysothamnus nauseosus*), and snakeweeds (*Gutierrezia* spp.). In the more sandy and higher elevated grassland areas, the yuccas are commonly associated with Indian ricegrass, or sand bunchgrass (*Oryzopsis hymenoides*), Navajo ephedra (*Ephedra viridis* var. *viscida*), shinnery oak (*Quercus havardi*), and beargrasses (*Nolina* spp.).

On the lower mountain slopes, bajadas, and mesas, the yuccas are commonly associated with such shrubs as coastal sage (*Salvia* sp.), chamise (*Adenostoma fasciculatum*), creosotebush (*Larrea tridentata*), *Jatropha cuneata,* ocotillo (*Fouquieria splendens*), blackbrush (*Coleogyne* sp.), beargrasses (*Nolina* spp.), sotols (*Dasylirion* spp.), sumac and poison ivy (*Rhus* spp.), catclaw (*Mimosa biuncifera*), Torrey ephedra (*Ephedra torreyana*), agritos (*Berberis trifoliolata*), snakeweeds (matchweeds) (*Gutierrezia* spp.), and *Lycium* spp. Many cacti and several agaves are also found admixed and associated with the yuccas of these regions. In the desert woodlands the yuccas

are also commonly associated with several species of oak (*Quercus* spp.), juniper (*Juniperus* spp.), and pinyon (*Pinus cembroides*).

In the montane forest, the yuccas are commonly associated with pines, spruces, and firs, as well as several broadleaved trees and many shrubs.

Trelease *(31, p. 123)* called attention to the fact that yuccas are characteristically xerophytes and stated, "Like other arborous Liliaceae, their larger representatives produce the impression of being the culmination of a vegetative type perhaps formerly of wide distribution, but now barely able to hold its own except in desert regions where competition between plants is less than elsewhere, while structural adaptation enables them to endure the rigors of this last resort." That yuccas are well adapted to desert conditions is unquestionable. Their large stems and rhizomes store considerable moisture, and, as Trelease pointed out, ". . . their leaves are well guarded against undue transpiration." Relative to the seeds of the fleshy-fruited yuccas, Trelease stated, ". . . their abundant endosperm suggests an adaptation to the dry regions." Although the seeds are well protected, supplied with abundant food, and retain their viability under natural conditions for several years, the writer has found that they require considerable moisture for germination. In many of the desert regions the rainfall is insufficient to germinate yucca seeds and, hence, the plant's reproduction is considerably diminished.

Yucca seedlings, as well as mature yuccas, are extremely persistent and well able to compete with the majority of their associates. This persistency is shown by the failure of one plant to penetrate the grounds occupied by another plant. It is questionable, however, if they can long endure the shade of the taller desert shrubs and trees, and it is doubtful if any plant can compete successfully with shinnery oak, and possibly several mesquites. The shinnery, or shin, oak is one of the most remarkable plants of our southwestern semideserts. On the Llano Estacado of western Texas it covers immense areas, often in pure, or almost pure, stands, and rarely exceeds 70 to 90 cm. in height. In the sandy regions near Plains, Yoakum County, Tex., shinnery oak occurs in stands that are a quarter or more mile square. The areas surrounding these stands are well covered with grasses and small annuals and perennials, including *Y. glauca,* but none of these plants intrude to any extent in the oak's domain. In fact, the stands are so dense that one hesitates to enter them in fear of hidden rattlesnakes. According to V. L. Cory,[4] the huge area over which the shinnery oak grows has been referred to as "the largest oak forest in the world." Similar competition between mesquite and *Y. glauca* occurs near Spur, Tex. The growth of the mesquite, however, is not so dense as that of the shinnery oak, and *Y. glauca,* as well as other perennials, are somewhat admixed with the mesquite.

YUCCA ENTERPRISES

Available Material

During World War II the writer conducted a survey to determine the amount of raw material that might be harvested from the denser concentrations of southwestern yuccas. The areas of these concentrations were determined by cyclometer readings, in conjunction with observations, contours, elevations, and distances calculated from maps. The density of the stands and weight

[4] In correspondence, dated Aug. 20, 1945. Mr. Cory was formerly range botanist, Texas Agr. Expt. Sta., Sonora, Tex., and is now field botanist, Southern Methodist University, Dallas, Tex.

TABLE 1.—*Southwestern yucca concentrations and estimated yields, 1943*

Locality	Harvestable area	Most distant point of harvestable area from locality	Species of *Yucca*	Average length of leaves	Yield per acre, range or average [1]		Total yield in area	
					Fresh leaves	Fresh crowns	Fresh leaves	Fresh crowns
	Square miles	*Miles*		*Inches*	*Tons*	*Tons*	*Tons*	*Tons*
Arizona:								
Apache	25	6	*elata*	--------	(0.55)	(0.85)	8,800	13,600
Florence	6	30	*arizonica* [2]	--------	(3.95)	--------	15,800	
Kingman	161	50	*schidigera*	21	0.2– .8	0.4–1.4	51,520	92,736
	38	50	*baccata*	20	--------	--------	13,440	15,360
McNeal	42	10	*elata*	--------	--------	--------	6,720	9,274
Nogales	2	5	*arizonica* [2]	--------	(1.00)	--------	1,280	
Vail-Benson	12	7	*arizonica*	--------	(0.65)	(0.95)	9,216	
Wilcox	18	12	*elata*	--------	--------	--------	7,688	10,944
California:								
Cima	165	40	*schidigera*	26	.3– .8	.8–1.5	63,360	110,880
Goffs	143	70	*schidigera*	26	.3– .8	.8–1.5	54,912	96,096
New Mexico:								
Carrizozo	9	37	*baccata* [2]	19	(1.40)	(1.65)	4,032	4,752
Deming	141	52	*elata*	19	.4– .8	.6–1.2	49,632	67,680
Las Cruces	151	95	*elata*	19	.3– .8	.5–1.1	53,328	72,720
Portales	148	50	*glauca*	19	.2– .8	.3–1.4	47,360	80,512
Rodeo	25	6	*elata*	--------	(0.55)	(0.85)	8,800	13,600
Tolar	109	45	*glauca*	18	.4– .8	.4–1.4	31,392	55,808
Tucumcari	120	55	*glauca*	18	.2– .8	.3–1.4	42,240	72,960
Texas:								
Dalhart	80	51	*glauca*	21	.3– .7	.5–1.2	30,820	53,760
El Paso	25	40	*elata* [2]	--------	--------	(0.33)	3,826	5,280
Van Horn	155	30	*faxoniana*	28	.7– .8	--------	[3] 88,198	
	85	30	*elata*	--------	.4– .6	.5– .8	28,660	37,232

[1] Figures in parentheses indicate average for area.

[2] Incomplete; based on insufficient weights.

[3] Contains approximately 9,920 tons of *Yucca torreyi* leaves.

of raw material were determined by actual counts and weights of harvested material from several half-acre strips scattered throughout the concentration. It was assumed that no area bearing less than one-fifth ton of fresh leaves per acre could be harvested profitably, and all such areas were deducted from the concentrations. Table 1 gives a summary of the principal native stands of yucca in the southwest, with estimates of yields.[5]

The possible yields of several other areas bearing dense concentrations of yucca have not been determined. The largest of these areas is that of *Yucca brevifolia* var. *jaegeriana* surrounding Cima, Calif. Unquestionably, this is the largest and densest yucca concentration in the Southwest. Other large concentrations observed by the writer are as follows:

Yucca brevifolia, south of Boran, and between Hesperia and Morango Valley, Calif.
Y. brevifolia var. *jaegeriana,* White Hill district, Mohave County, Ariz.
Y. arizonica, Fresnal Canyon, Baboquivari Mountains, Ariz.
Y. glauca, Railroad Mountain, near Elkins, N. Mex., and vicinities of Calhan, Kiowa, and Monument, Colo.

Reported concentrations not observed by the writer are:

Yucca brevifolia, 12 miles west of Congress Junction, Ariz.
Y. brevifolia var. *jaegeriana,* between Littlefield and Grand Wash, Ariz.
Y. glauca, near Chillicothe and Sedgwick, Colo.

Reported dense concentrations of *Y. glauca* near Spur and Lubbock, Tex. *(18)* were not found by the writer. It is believed that these stands have been taken over by shinnery oak and mesquite or that the lands have been cleared for agricultural development.

Uses and Potential Uses of Yucca

Yuccas had an important place in the early southwestern Indian and Mexican cultures. Fiber and twine, identified as made from yucca and determined to be around 2,000 years old, was found in Canyon del Muerto ruins, Arizona, and Lapham *(21)* reported that beams and timber of *Yucca brevifolia* have been found in ancient cliff dwellings. Early and present-day uses of yuccas for food, beverages, detergents, medicines, clothing, construction of dwellings, and household articles by the Indians and Mexicans were reported by Trelease *(31),* Standley *(29),* Yanovsky *(37),* Kearney and Peebles *(20),* and others. In the opinion of Bell and Castetter *(2)* ". . . yucca ranked foremost among the wild plants utilized by the inhabitants of the Southwest. It holds this place because of the great variety of uses to which it could be put and to the wide accessibility of the genus within the Southwest."

Probably the first large-scale utilization of yucca in the United States was the use of *Y. elata* and *Y. glauca* to supplement cattle feed during the drought from 1916 to 1919. Forsling *(14),* Wooton *(36),* Jones and Conner *(18),* and others reported that the dead leaves were burned off the yuccas and the plants cut and chopped for silage. The chopped yuccas, supplemented with such concentrates as cottonseed meal, were found to be a practical means of maintaining cattle during severe droughts.

[5] See typewritten report filed in the Division of Cotton and Other Fiber Crops and Diseases, Plant Industry Station, Beltsville, Md.: WEBBER J. M. YUCCA STANDS AND DISTRICTS, AND ESTIMATED YIELDS, WITH MISCELLANEOUS NOTES ON HARVESTING, FIBER AND COSTS. 76 pp., illus. 1943. Revised 1944.

See also mimeographed report: ROBINSON, B. B., and WEBBER, J. M. YUCCA. Bur. Plant Indus., Soils, and Agr. Engin. 6 pp. 1948.

According to Cruse *(11),* the chemical composition of yucca on a dry-weight basis was 4.4 percent protein, 6.7 percent ash, 1.5 percent fat, 3.2 percent fiber, and 49.2 percent carbohydrates.

Undoubtedly the most extensive use of yucca has been for the production of fiber. According to Botkin and associates *(4, 5, 6)* the leaves contained approximately 50 percent moisture and about 40 percent chemically extractable fiber. These authors found that the strengths of *Y. glauca* and *Y. elata* fiber were, respectively, about 45 and 47 km., as compared with 33 km. for jute; 43 for palma istle and African sisal; 47 for Wisconsin hemp; and 62 for Manila hemp (abacá). In baccate-fruited species, they reported the following averages, in kilometers: *Y. baccata,* 60.2; *Y. torreyi,* 61.1; *Y. schidigera* 50.4; and *Y. faxoniana,* 54.0. Botkin and Shires concluded that the fibers of *Y. glauca* and *Y. elata* were suitable for making twine and burlap, while the fibers of the other tested species were strong enough for making binder twine and ordinary rope. It is generally considered, however, that yucca fibers do not possess values that would make it a strategic material, except in extreme emergency.[6]

Within recent years yucca juice has come to be considered of greater value than the fiber. Its utilization as a base in liquid fertilizers is said (1) to reduce surface tension of irrigation water, greatly assisting penetration in heavy soils; (2) to assist in soil flocculation to a marked degree; and (3) to serve as a carrying agent for the plant-food chemicals. Relative to this use Haynes [7] stated, ". . . yucca extract, a liquid organic acid . . . has proven to be the best medium known to date for quick assimilation. The yucca extract itself is rich in the vital minor elements including boron, iron, magnesium, manganese, copper and zinc."

The juice is said to be widely used as a carbon dioxide stabilizer in the control of oil fires, and saponin from yucca is considered a good base for soaps, shampoos, cleansing powders, and tooth pastes and powders.

The rhizomes of yucca are reported to be a rich source of a female hormone, desorycorticorcerone, which is of great value in gynecological work.

Katz, Hall, and Petersen *(19)* suggested that *Y. brevifolia,* particularly the wood from which the water-soluble constituents have been extracted, might prove a source for lignaceous materials, possibly valuable in synthesis of vanillin.

In a treatise on California wild tree crops that possibly could be utilized during emergency periods, as well as under normal conditions, Wolf *(35)* reported that the seeds and dry pods of the Joshua-tree *(Y. brevifolia)* are fairly good feed materials. His analysis of the pod material showed that it compared very favorably with dried orange peel. Wolf's figures for proximate percentages of chemical composition of harvested pods in comparison with that (in parentheses) of dried orange peel, were as follows: Water, 7.6; protein, 6.7 (5.8); fats, 2.0 (0.7); fiber 16.8 (10.6); nitrogen-free extract (carbohydrates) 60.0 (64.7); and ash (mineral matter) 6.9. He reported the seed of the Joshua-tree to contain 34.4 percent oil, as compared with 36.4 percent for flaxseed, 21 to 23 percent for cottonseed, and 18 percent for soybeans. The seed meal, or residue left after oil extraction, was roughly equivalent to wheat bran (in parentheses): water, 9 percent; crude protein, 15.5

[6] See footnote 5, p. 7.

[7] HAYNES, J. D. A NEWER METHOD OF LIQUID FERTILIZATION. 7 pp. n.d. Liquinox Co., Orange, Calif. [Processed.]

(15.8) percent; fat, 5 (5) percent; fiber 15 (9.5) percent; nitrogen-free extract 53 (54.3) percent; and ash, 2.5 (6.0) percent. Wolf *(35, p. 15)* stated, ". . . the Joshua Tree oil is a clear, light yellow oil, practically tasteless and odorless. Its iodine number of 120.3 indicates that it is a semi-drying oil which along with its other characteristics indicates that it may be found to have some value for other uses than merely as an edible oil for salads, shortening, etc."

Cruse *(11)* stated that several authors have reported fructose, fructosans, dilevans, and glucose present in several yucca species. The fruits of the baccate species were very sweet, and when they were drying in an oven they gave off a very sweet candylike odor. A single fruit of *Y. baccata* or *Y. arizonica* will often fill a quart jar.

Economic Factors

In order that the potential values of yucca may be thoroughly understood, further investigations should be conducted. Under normal conditions, however, it is doubtful if native yuccas could be economically used for large-scale projects in the United States. Even the use of yuccas in a combination of two or three of the most promising enterprises must be considered speculative at the present time. Although in the majority of yucca concentrations there are very dense areas, the ordinary or average stand would yield only approximately 0.55 ton of fresh leaves, or 0.85 ton of fresh crowns per acre. Reliable information indicates that the rate of harvesting and assembling of the material will not greatly exceed 500 pounds of leaves or crowns and 2,000 pounds of stems with crowns per day per workman. The transportation of raw material to a factory is one of the major expenditures. Although in some localities the terrain may permit trucks to move with little difficulty, in others sand, gullies, and mountains would prohibit trucking or make it very costly.

The present experimental data as to quantity, quality, or composition of yucca fiber, extract, and hormones are not sufficient to determine what would be obtained or expected in large-scale operations. The common reductions or losses in large-scale operations, in conjunction with excessive costs of collecting and trucking native yucca material, indicate that the majority of the proposed yucca projects would allow a very narrow margin of profit at the best. There is also some opposition to large-scale yucca harvesting. In areas where yuccas fail to reproduce readily or in the drier areas where the plant's natural values are extremely important to the land and to the ranchers, the yuccas should not be harvested except for use in extreme emergencies.

To overcome many of the economic difficulties involved in the utilization of native yuccas, it has frequently been suggested that the plants should be cultivated. The culture of yuccas would not only eliminate some of the difficulties involved in the use of native plants, but very likely would greatly improve the plant. There is sufficient evidence to indicate that yuccas will grow very well on much of our poorer agricultural lands. If such plantings were cultivated to conserve rainfall or lightly irrigated, the plants would be considerably more vigorous. Undoubtedly the greatest benefit of growing yuccas would result from the selection of native plants most suitable for economic use. The writer's studies indicate that through simple selection a field of better and more uniform plants than occur in nature would not be difficult to establish.

Although yuccas are quite free from diseases, in several areas they are badly

damaged by insects and rodents. It is not known whether these infestations could be controlled or whether they would increase in cultivated yucca fields. If yuccas were cultivated, it is likely that unforseen problems and difficulties would develop.

PAST AND FUTURE OF YUCCAS

In referring to the baccate-fruited yuccas, Trelease *(31, p. 123)* stated, ". . . that they have been derived from the thin-seeded capsular species seems more probable than the reverse . . ." It appears that Trelease was led to this conclusion by the fact that the seeds of the fleshy-fruited yuccas are better adapted to desert conditions than those of the capsular-fruited species. In the present monograph, Trelease's conclusions are confirmed by the fact that the fibrous-rooted (baccate) species are more characteristic of the drier sections, while the rhizomatous (capsular) species are characteristic of the more humid sections.

Unquestionably several species of yucca are the oldest or among the oldest living plants of the deserts. Since the discovery by Laudermilk and Munz *(22, 23)* of yucca remains in the dung of the extinct ground sloth *(Nothrotherium)* there has been little doubt that yuccas were formerly more widely distributed. These authors and Dr. Arthur D. Howard found that the ground sloth fed mainly on the Joshua-tree, and by comparisons of the plant remains of the dung with existing floras they concluded that the climate in the area the sloth inhabited was distinctly more humid than today. These findings and conclusions and the large, grotesque appearance of several yuccas have attracted much attention; in fact, they are not uncommonly depicted in reconstructions of prehistoric, mesophytic forests. Within recent years, several pictures of immense ground sloths uprooting and completely devouring huge Joshua-trees have appeared. These paintings are undoubtedly deceptive, as it is very likely that all yuccas of the past, including the Joshua-tree, were of a rhizomatous type, forming large, dense clumps, and of comparatively low stature.

Regardless of the present wide distribution and large concentrations of yucca, its future appears very dim. This gloomy outlook is mainly the result of the plant's failure to reproduce and its destruction by man. Throughout the Southwest yucca seedlings are very rare and mainly limited to the more humid sections. In 1918 Wooton *(36, p. 13)* observed the lack of yucca seedlings and concluded, ". . . reproduction from seed, while possible, is but remotely probable in the open country. . . . It thus appears that most of the species here listed, if used up, are not likely to return." [8] By the hands of man, yucca has suffered greatly through agriculture, various enterprises, fire, and wanton destruction. In 1918 Jones and Conner (*18*) reported large concentrations of *Yucca glauca* in the vicinities of Lubbock and Spur, Tex. At the present time, in these localities, as well as elsewhere in the more livable regions of the Southwest, large tracts containing yucca have been cleared for necessary agriculture. V. L. Cory [9] stated, "The capsular species of yucca very likely are on the decrease in all parts of west Texas, especially where livestock are being grazed. These plants are of low growth, and the inflorescence shoots are highly palatable to

[8] Wooton lists *Yucca elata, Y. glauca, Y. torreyi (macrocarpa), Y. baccata, Y. brevifolia, Y. rupicola,* and *Y. faxoniana (Samuela).*

[9] See footnote 4, p. 5.

all types of livestock. It is rare for any of them to get into flower, and even more rare for them to produce seed. In the passage of time, the old plants die and there is no reproduction." In many sections in southern Texas the writer has seen areas so heavily grazed by sheep or goats that yuccas and other plants considered as emergency stock feed have been exterminated.

With reference to the preservation of the Joshua-tree in California, Munz *(27)* stated, ". . . large tracts of Joshua land have been cleared by homesteaders, many of whom have later had to abandon their clearings. It might be expected that the open vegetation of the desert would be free from devastation by fire, but for many miles along the highway between Victorville and Cajon Pass, Calif., there is a burned area of long-leaved Joshua."

The writer has seen large burned areas of *Y. schidigera, Y. elata, Y. glauca,* and *Y. rostrata.* Although in many cases such burned yuccas will recover, in others they are so badly burned or the area is so heavily infested with rodents[10] that recovery is impossible.

Under the introductory paragraphs and the section on Yucca Enterprises, it has been shown that yuccas have been utilized in many ways. These projects have involved practically all yucca species, and several of them have necessitated the cutting of enormous quantities of yuccas over vast areas. Although the best information indicates that the majority of harvested plants will sprout and within a few years renew the crop, this evidence is meager and limited to only a few species. Furthermore, some evidence and observations indicate that under certain conditions these few species may not recover following harvesting. In reference to yuccas as stock feed, Wooton *(36, p. 14)* stated, "It should be clearly understood that the supply of this emergency feed is not by any means inexhaustible; in fact, on many ranches it is scarce or very limited in amount; also that natural renewal is slow with the best species and improbable with others, while it is reasonably rapid with but one species *(Yucca glauca).*"

Many yuccas are damaged by breaking off parts for decorative material, and many others are moved to home gardens where they lack proper care and soon die. There have been frequent reports of Joshua-trees being wantonly burned and hacked, and the writer has observed many fine specimens of other trunklike species mutilated in various ways by tourists and campers.

Undoubtedly self-sterility and cross-pollination add to the insecurity of several species. *Y. thompsoniana* and *Y. reverchoni,* as well as several other species, are comparatively scarce, are quite self-sterile, and occur in areas dominated by other species, with which they unquestionably hybridize quite freely. If these comparatively self-sterile plants depended entirely upon seed for reproduction, it is very probable that they soon would be eliminated and replaced by the more abundant species and by hybrid derivatives. In many parts of the Southwest the confused nature of the yuccas is possibly indicative of such species conversions.

With reference to the large forest of *Y. brevifolia* var. *jaegeriana* in California, Munz *(27)* stated, "Early action is necessary, if we are to preserve an

[10] In all of the drier parts of the Southwest rodent damage to yuccas is common. Although both rabbits and wood rats often destroy young growth, wood rats are particularly damaging. These rats not only eat the flowers, fruit, and leaves, but in badly infested areas they frequently destroy the entire head of leaves and even gnaw into the trunklike stems. In heavily infested areas from 30 to 40, and even as high as 65 percent, of the yuccas are badly damaged. Such infestations are quite common in *Y. schidigera* and *Y. elata.* Areas of damage are usually from one-fourth to several square miles in area.

outstanding example of so strange and beautiful a forest . . . If future generations are to have any adequate concept of the original vegetation and other desert life in an undisturbed condition, and if the short-leaved Joshua is to be maintained at all, an area large enough to assure its protection should be set aside." Undoubtedly, such protection would prolong the existence of yuccas and it should be provided for the majority of the species.

YUCCA STUDIES AND PLANT CHARACTERS

In 1902 William Trelease's monograph *(31)* on yuccas was published. This work represented studies begun some 10 years previously, and up to 1911 it was supplemented by short articles. Despite the difficulties involved in yucca studies and the hardships of desert travel at the beginning of the present century, William Trelease's accomplishments were of a high magnitude, and his ability to recognize distinct forms or species with scanty material seems almost incredible. In several instances he separated well-defined species in localities where the plants were highly variable, where species intergraded into each other, and where the typical species were all but lacking. In the majority of these cases, however, with today's known range, pure concentrations of the type have been found, possibly a hundred or even a thousand miles away from the type locality.

Although Trelease occasionally mentions instability within yuccas, it is apparent that he did not know how extensively it occurs. Furthermore, some of his descriptions indicate that he failed to consider whether variations were caused by environmental causes or by genetical differences. As a result of these failures, a few of Trelease's descriptions do not include common variations caused by physiological reactions; others are too broad and include apparent hybrids. That these failures were mainly the result of Trelease's inability to cover a wide range is indicated by the fact that in several instances his key character to a species is prevalent in only a relatively small proportion of the present known range of the species.

In 1938 and 1947, the Arnold Arboretum of Harvard University published parts one and two, respectively, of Susan Delano McKelvey's treatise *(24, 25)* entitled "Yuccas of the Southwestern United States." This publication contains excellent references to the historical nomenclature and morphological analyses of yuccas. In it are cited numerous collections and herbarium specimens. In reviewing the literature, McKelvey mentions that Engelmann and other early investigators had difficulty in finding specific characters and considered yuccas unstable. McKelvey confirmed these difficulties and concluded *(24, p. 6)* that the inconstancy "makes it obvious why any characterization of groups or of a species must be understood to include reservations as to exceptional plants," and *(25, p. 7)* that, "It should be realized that, even in important characters, instability is to be expected in every *Yucca* species—one acquires a 'sense' for reasonable as against unreasonable variations."

Throughout McKelvey's yucca treatise it is clear that she believes hybridization largely responsible for instability. In several instances she considers named types hybrids, and in her Discussion of Characters *(25)* stated, "The moth which works apparently not only between plants of one but of several species when these come into proximity is, over the years, doubtless responsible for many individual peculiarities." Despite this recognition of hybridization, McKelvey segregates several new species that are extremely variable,

that intergrade into two or more types, and that exhibit no characteristics typical only of the new forms. Although McKelvey commonly associates teratological variations with possible yucca hybrids, such variations are not usually indicative of hybrids.

McKelvey *(25, p. 8)* commented on the characters that were useful and those that were of little value in determining yucca identities. Relative to the leaf, she stated, "The texture of the mature blade, whether grass-like and rather soft to somewhat flaccid, or wiry and resilient, is one of the characters distinguishing series in *Chaenocarpa*." Four of McKelvey's six series in *Chaenocarpa* are mainly differentiated by leaf texture. The writer's field and nursery comparisons of leaves of thousands of plants in these series indicate that the series and the majority of species in them cannot be separated on the basis of leaf texture. Throughout the present monograph it is shown that leaf texture is extremely variable and dependent upon environmental conditions and genetical composition.

McKelvey also found the color and texture of the capsules useful in determining identities. Although the writer believes these characters to be more stable than those of the leaves, they are nevertheless quite variable. In several species the capsules are commonly white to dark brown, smooth to rough, and thin- to thick-walled. Although it is not known what causes these variations, considerable evidence indicates that color and possibly smoothness depend upon environmental conditions. In general, it appears that if the plant is in an open sandy area the capsules are lighter colored and smoother than those of plants in rocky or gravelly mountain areas.

Relative to whether the capsules are constricted or symmetrical McKelvey *(25, p. 11)* stated, "Some capsules show a tendency to constriction, possibly not always caused by the work of the yucca moth; those with a thin wall seem to be more subject to it than those with a thick wall — it is not a dependable character." Although evidence indicates that the work of the yucca moth is responsible for capsular constriction, the writer believes that it has little to do with the thickness of the capsule wall. Possibly the capsules with the thinnest walls the writer has seen occur on *Yucca elata* plants near Aguila, Ariz. None of the capsules of these plants exhibited constrictions. Constricted capsules occur frequently in species having small capsules, and rarely, if ever, in pure species having large capsules. Unquestionably the constrictions in both the capsular- and baccate-fruited yuccas are mainly caused by the failure of the ovules to develop in the region of the ovary pierced by the moth's ovipositor. It is very likely that the failure of the ovules to develop depends upon how deeply the ovary is pierced, which probably depends upon the diameter of the ovary and the size of the placenta as well as the thickness of the wall, and possibly such features as length of style and shape of flower. Regardless of the causes of fruit constriction, outside of hybrid zones, the presence of the character or the lack of it appears to be quite constant.

It should be realized that many of the morphological problems and growth peculiarities of yuccas can be solved and evaluated only when the plants are grown under uniform conditions and are thus subjected to comparison and experimentation. Such studies, however, have been greatly handicapped by the extremely slow growth and development of the plant and by its large size.

In the present monograph, evidence is presented that indicates variations in yuccas are mainly of three types: (1) Environmental; (2) minor genetical; and (3) major genetical. Variations caused by environmental and minor genetical differences are to be expected and are not out of line with species or

form characterizations. On the other hand, variations owing to major genetical differences are not in line with species or form characterizations, and plants showing such variations appear either (1) to possess specific characters of two or more species or (2) to be major mutants in one or two specific characters of a species. Plants exhibiting mutation are rare and may possibly be considered "exceptional" plants of a particular type. They do not exhibit specific characters of species or forms other than those of the group to which they belong.

Variants that exhibit characteristics of two or more species or forms appear to be intertype hybrids and recombinations. Although phenotypically these plants are frequently midway between species, they are more often gradients between the apparent types involved. Such gradients often form large transitional zones between the ranges of various yucca species. The plants within such a zone usually exhibit a gradation from one type to another, and occasionally colonies or even large patches of fairly uniform plants appear to have been set aside and become well established. As the plants in these patches can readily be characterized and appear rather stable, they are easily segregated as types. Nevertheless, they fit into a gradation and exhibit specific or slightly modified specific characters of the species or form involved in the gradation. To separate such patches into named types only increases the taxonomic perplexity of yuccas.

In order to minimize the confusion, it appears that species scopes should be broadened to include minor differences and that those plants which are combinations of well-defined types should be recognized as hybrids or transitional forms. To identify satisfactorily all transitional types or forms would be a tedious undertaking and without great value.

NATURE AND RANGE OF STUDY

The present botanical study was a part of an 8-year survey of the yuccas of the southwestern United States conducted to evaluate the plants as a possible source of cordage fiber. Although the botanical work is academic in nature, many of the data presented have a direct bearing upon the possible commercial utilization of the yuccas.[11]

The botanical part of the work was carried out primarily to overcome the taxonomic confusion mentioned above and to determine the cause of the peculiar growth behavior of the yuccas. In the accomplishment of these objects, it was hoped that practically all yuccas in the Southwest could be identified and that many of the problems relative to the growth of the plant would be clarified. One of the main interests in the study was concerned with the problems that deal with the establishment of variations, their perpetuation, and their distribution.

Although the study was limited chiefly to native stands and full-grown

[11] For details of the economic utilization, concentrations, determinations, and yield of yucca, see typwritten reports filed in the Division of Cotton and Other Fiber Crops and Diseases, Plant Industry Station, Beltsville, Md.:

WEBBER, J. M. YUCCA STANDS AND DISTRICTS, AND ESTIMATED YIELDS, WITH MISCELLANEOUS NOTES ON HARVESTING, FIBER AND COSTS. 76 pp., illus. 1943. Revised 1944.

———CATTLE AND RODENTS IN RELATION TO ECONOMIC UTILIZATION OF YUCCAS. 10 pp., illus. 1944.

———ECONOMIC USES OF YUCCAS IN SOUTHWESTERN UNITED STATES, WITH FOOTNOTES ON CULTIVATION AND GROWTH RATES. 25 pp., illus. 1945.

nursery plants, it also included the collection of numerous specimens and their comparison in the laboratory. These specimens were mainly standard herbarium sheets of dried plants or parts of plants, dried fruit, and preserved flower parts.[12]

The studies of native stands, roughly speaking, extended from west-central Texas (from Crystal City north to Childress) to the Pacific Ocean; and from the Mexican border north to south-central Colorado, Utah, Nevada, and California. Within this area, numerous plants were studied throughout many parts of the ranges of the various species. In addition, experimental plots and working field stations were established in several localities.

The majority of the nursery plants were grown from seeds in open field plots at the California Citrus Experiment Station and the United States Regional Salinity Laboratory, Riverside, Calif. The nursery plots were subjected to semicultivation and to one light furrow irrigation every 8 weeks during the summer dry season.

METHOD OF PRESENTATION

In evaluating yuccas, the writer has followed the rule that species must be separated on the basis of more or less evident distinctions and that there must be little intergradation from one species to another. This does not mean that all species have the same degree of distinctness, as some are well defined by several stable characters and others are so variable that they are difficult to characterize. In the case of a species with variable characters it has been possible to describe only the range of characteristics of the whole group, or, in a few instances, to divide them into lesser groups, varieties, or forms that exhibit some degree of distinctness. A species and its varieties, however, are apparently very similar in genetic constitution, and not uncommonly the variations found within the species are quite similar to the variety.

Of the 28 to 32 species listed as occurring within the range of the present survey, only 21 species are recognized. This is neither extreme consolidation nor liberalism. It is mainly the result of the writer's species concept, which eliminates apparent hybrids and gradients from species status and retains taxonomic units clearly marked by evident characters. The most extreme consolidation would be a reduction to 14 species, mainly by calling the following species subspecies or varieties: (1) *Yucca baileyi, Y. angustissima,* and *Y. constricta* under *Y. glauca;* (2) *Y. reverchoni* under *Y. rupicola;* (3) *Y. thompsoniana* under *Y. rostrata;* (4) *Y. faxoniana* under *Y. carnerosana;* and (5) *Y. torreyi* under *Y. treculeana.* Such combining, however, would only morphologically equalize species rank. It would not reduce the number of distinct taxonomic units that should bear names.

Descriptions are based upon native plants in various sections of the species range. Apparent hybrids and extreme variants that are not in line with the general characterization of the species are not included in the descriptions. Likewise, plants exhibiting local environmental effects, such as roadside plants and plants receiving extra cattle or sheep manure, have been excluded from the descriptions. However, many of the apparent hybrids and variants are included in the general treatment of the species or species group.

Unless otherwise noted, all measurements are as follows. *Clumps:* Diameter,

[12] These specimens are at the Plant Industry Station, Beltsville, Md., and the University of California Herbarium, Berkeley, Calif.

actual measurement or careful estimate made with the aid of a meter rod adjacent to the plant; number of leaf heads (crowns), actual count or careful estimate based on division of clump into equal parts. *Stems:* Diameter measured just above basal swelling, or approximately 30 cm. above soil level; height, from ground level to center of leaf head or base of imbricated bud. *Leaves*: Dimensions of blade only; width, the greatest width, flattened width in case of convex leaves. *Flower parts:* Range mainly the average measurement of 5 flowers at anthesis from a single inflorescence of each of 50 widely distributed plants; average (given in parentheses), the mean of the preceding range averages. *Fruits:* All measurements and descriptions are of dried matured fruits. *Range* and *average* measurements in general are based mainly on 50 to 1,500 individual plants. *Bajada,* means an alluvial fan; upper or lower bajada, i.e., the upper or more elevated part of the bajada and the lower or less elevated part (Benson and Darrow (*3*) and others).

SECTIONS OF THE GENUS *YUCCA*

Fruit indehiscent.
- Leaf blade large, broad, mainly thick, concavo-convex, rigid and swordlike, or in *Y. schottii* somewhat thin and flexible; fruit large and fleshy, eventually becoming pendent and drying with a rough leathery, dark brown or black, often gummy, covering; seed rough, more or less thickened, flat, without marginal wing (species Nos. 1 to 8).....I. SARCOCARPA.
- Leaf blade small, thin, narrow, plano-convex, rigid and stilettolike; tip concavo-convex; fruit dry and spongy, erect, spreading or variously directed; seed smooth, thin, without marginal wing (species No. 9).....II. CLISTOCARPA.

Fruit dehiscent. Leaf blade thin, mainly narrow, plano-convex, flexible, or in *Y. rupicola* and *Y. gilbertiana* broad and in *Y. neomexicana* and *Y. gilbertiana,* concavo-convex and rather rigid; fruit a dry capsule, soon becoming erect; seed smooth, thin flat, with or without marginal wing.
- Stigma capitate; capsule loculicidally dehiscent (species No. 10)..... III. HESPEROYUCCA.
- Stigma lobed; capsule commonly septicidally, or occasionally septicidally and loculicidally dehiscent (species Nos. 11 to 21).....IV. CHAENOCARPA.

KEY TO *YUCCA* SPECIES

INDEHISCENT-FRUITED SPECIES

1a. Fruit fleshy; leaf blade large, coarse, and swordlike; leaf margin entire or with free fibers; perianth segments thin, expanding equally or nearly in two series, seed thick.
- 1b. Perianth segments united into slender tube; filaments inserted on tube and free from each other; heads of leaves symmetrical; leaf blade very rigid, broad, strongly concavo-convex.
  - 1c. Peduncle long, exceeding the foliage; panicle ellipsoidal or oblately ellipsoidal; perianth segments commonly united for 2.5 cm...1. Y. CARNEROSANA.
  - 2c. Peduncle short, not exceeding the foliage; panicle broadly conoid; perianth segments rarely united for more than 1.5 cm.....2. Y. FAXONIANA.
- 2b. Perianth segments not united into tube, but slightly connate at base; filaments inserted at base of segments and united to each other; heads of leaves rather symmetrical; leaf blade commonly rigid, rarely flexible, fairly broad or narrow, moderately concavo-convex, or rarely somewhat flattened.
  - 1c. Pistil short, 1.8 to 4.0 cm.; plant commonly fruticose or arborescent, with few stems and with heads of leaves in a rather open clump.
    - 1d. Leaf margin without free fibers, or in age with a few fine straight fibers; ovary rather slender.

1e. Panicle with few branches and commonly puberulent; leaf blade thin and flexible.....3. Y. SCHOTTII.
2e. Panicle with many branches and commonly glabrous; leaf blade thick and rigid.....4. Y. TRECULEANA.
2d. Leaf margin with free fibers; fibers rather coarse and curly; ovary rather stout.
1e. Ovary gradually tapered from base to style; style 4 to 8 mm. long. 5. Y. TORREYI.
2e. Ovary abruptly tapered at apex to style; style 1 to 2 mm. long. 6. Y. SCHIDIGERA.
2c. Pistil long, 4.5 to 9.0 cm.; plant acaulescent or caulescent, with numerous stems or with heads of leaves in rather dense clump.
1d. Plant caulescent with rather tall, erect or assurgent stems; leaf blade narrow (1.8 cm.); leaf margin with few fine fibers.....7. Y. ARIZONICA.
2d. Plant acaulescent or with short procumbent stems; leaf blade broad (3.8 cm.); leaf margin with coarse, often curly, fibers.....8. Y. BACCATA.
2a. Fruit spongy and dry; leaf blade small, fine and stilettolike; leaf margin minutely denticulate; perianth segments thick, fleshy, the outer series scarcely expanding, the inner series expanded about half their length, seed thin. 9. Y. BREVIFOLIA.

DEHISCENT-FRUITED SPECIES

1a. Leaf margin yellow, brown, or greenish yellow; corneous; completely or partially denticulate, or rarely smooth.
1b. Stigma capitate; capsule obovoid or nearly cylindrical, tipped with an abrupt, short point, loculicidally dehiscent.....10. Y. WHIPPLEI.
2b. Stigma 3-lobed, 6-notched; capsule ellipsoidal or somewhat ovoid, tapering at apex into a long, slender point.
1c. Plant aborescent.
1d. Plant tall (2.3 m.); branches short; head of leaves large, symmetrical. 11. Y. ROSTRATA.
2d. Plant medium tall (1.4 m.); branches comparatively long; head of leaves small, rarely symmetrical.....12. Y. THOMPSONIANA.
2c. Plant acaulescent.
1d. Plant an open clump; leaf blade 20 to 25 mm. wide, undulate, dark green .....13. Y. RUPICOLA.
2d. Plant a dense clump; leaf blade 10 to 20 mm. wide, not undulate, light glaucous green.....14. Y. REVERCHONI.
2a. Leaf margin at first entire, thin, paperlike, white or rarely green, but soon finely filiferous.
1b. Leaf blade concavo-convex, short (15 to 30 cm.), commonly lanceolate; capsule small and deeply constricted, attentuate-beaked, with valve points outward at maturity.
1c. Leaf blade linear to lanceolate; peduncle long, usually exceeding the foliage; basic flower color white.....15. Y. NEOMEXICANA.
2c. Leaf blade lanceolate to broadly lanceolate, peduncle short, rarely exceeding the foliage; basic flower color yellow.....16. Y. GILBERTIANA.
2b. Leaf blade plano-convex, commonly linear, rarely lanceolate, capsule usually large, constricted or not constricted, mucronate-beaked, with valve points mainly inward at maturity.
1c. Acaulescent or rarely with thin, short stems up to 1 m. tall; head of leaves commonly small.
1d. Scape short (0.2 to 1.6 m.); peduncle short (0 to 1.0 m.); inflorescence a simple raceme or with a few abortive or short branchlets.
1e. Capsule rarely, and then only slightly, constricted.
1f. Style dark green, very tumid.....17. Y. GLAUCA.
2f. Style white to fairly dark green, narrow to somewhat swollen. 18. Y. BAILEYI.
2e. Capsule usually constricted, constriction deep.....19. Y. ANGUSTISSIMA.
2d. Scape long (1.5 to 3.2 m); peduncle long (0.7 to 2.0 m.); inflorescence paniculate, capsules usually constricted.....20. Y. CONSTRICTA.
2c. Arborescent, with thick, long stems, head of leaves commonly large. 21. Y. ELATA.

INDEHISCENT-FRUITED YUCCAS

1. *Yucca carnerosana*

(Palm barreta, palm samandoca)

Yucca carnerosana (Trel.) McKelvey, Yuccas Southwest. U. S. 1: 24, *pls. 6 and 7.* 1938.

Yucca australis Trel., Mo. Bot. Gard. Ann. Rpt. 4: 190. 1893, as to Pringle specimens only. Not *Y. australis* (Engelm.) Trel., 1902.

Samuela carnerosana Trel., Mo. Bot. Gard. Ann. Rpt. 13: 118. 1902.

Plant arborescent, symmetrical, simple, or rarely a tall, rather dense clump of stems and heads of leaves, with stems contiguous at base and spreading toward top; stems commonly 1 or 2, of equal or unequal height, rarely up to 8 of varying height, the older trunklike, up to 5 m. tall and 35 cm. in diameter, rarely once- or twice-branched toward top, the branches short, assurgent; leaves large in terminal head, the blade 51 to 100 (68) cm. long, 5.2 to 7.5 (5.8) cm. wide, rigid, spreading; scape rather long, stout; panicle slightly above foliage, ellipsoidal or oblately ellipsoidal, rather densely branched with persistent white bracts; flowers expanding to 45 to 90 mm., white; sepals 67 to 94 (83) mm. long, 13 to 21 (17) mm. wide; petals 65 to 93 (82) mm. long, 20 to 28 (26) mm. wide; tube portion of sepals and petals 17 to 30 (25) mm. long, filaments 22 to 29 (26) mm. long; pistil 48 to 63 (57) mm. long; ovary 6 to 9 (8) mm. in diameter; style 6 to 10 (8) mm. long; fruit (immature) oblong. (Pls. 1 and 2.)

TYPE: Limestone hills, Carneros Pass, Carneros, northeastern Mexico, *C. G. Pringle 3912,* May 11, 1891; Mo. Bot. Gard. Nos. 135656-57.

RANGE: Only in south-central Brewster County, eastern Rio Grande Big Bend, Tex. Although it occasionally occurs in small patches along the lower bajada washes, it is usually thinly scattered on the eastern and southeastern foothills of the Carmen Mountains between 1,600 and 2,500 feet elevation. The greater part of the range of *Yucca carnerosana* is reported in Mexico, where it extends some distance below the Tropic of Cancer.

The heads of leaves of the younger shoots are extremely large and symmetrical and hemispherical in shape. The leaves are large, dark blue green, with very conspicuous fibers along margins of the young ones. The flower bud, as well as the matured inflorescence, is extremely large and showy. The flowers are waxen white and have a very pleasant fragrance. The robust growth and large inflorescence of *Y. carnerosana* is very attractive and can be seen a mile or more away. *Y. carnerosana* usually flowers between March 15 and April 15, but late off-season summer and fall blooming is common.

The species exhibits little variation. It is associated with *Y. torreyi* and *Y. rostrata.* Although the writer has found no evidence that *Y. carnerosana* hybridizes with other yuccas, McKelvey *(24)* cited a specimen that she believed to represent a hybrid between the species and *Y. torreyi.*

2. *Yucca faxoniana*

(Palma)

Yucca faxoniana (Trel.) Sarg., Man. Trees N. Amer., p. 121, *fig. 106.* 1905; ed. 2, p. 115, *fig. 111.* 1922.

Yucca australis Trel., Mo. Bot. Gard. Ann. Rpt. 4: 190 (as to Texas plants). 1893. Not *Y. australis* (Engelm.) Trel. 1902.

Y. australis Coult., U. S. Natl. Herbarium Contrib. 2: 436 (in part). 1894.

Y. macrocarpa Sarg., Gard. and Forest 8: 305. 1895, excluding synonymy. Not *Y. macrocarpa* Engelm., 1881.

Samuela faxoniana Trel., Mo. Bot. Gard. Ann. Rpt. 13: 117. 1902.

Plant arborescent, symmetrical, simple, or rarely a tall open clump of stems and heads of leaves, with stems contiguous at base and spreading toward top; stems commonly 1, rarely up to 6, of varying height, the older trunklike, up to 6.5 m. tall and 40 cm. in diameter, occasionally once or twice assurgently branched; leaf blade 48 to 85 (59) cm. long, 4.5 to 7.0 (6.4) cm. wide, rigid, spreading; scape rather short and stout; panicle 0.10 to 0.25 of its length within foliage, broadly conoid, rather openly branched, with white or occasional purple-tinged persistent bracts; flowers expanding 40 to 70 mm., white; sepals 55 to 87 (69) mm. long, 15 to 17 (16) mm. wide; petals 54 to 85 (68) mm. long, 19 to 20 (19.5) mm. wide; tube portion of sepals and petals 10 to 18 (14) mm. long; filaments 21 to 32 (27) mm. long; pistil 45 to 59 (51) mm. long; ovary 6 to 8 (7) mm. in diameter, narrowly ovoid; style 5 to 7 (6) mm. long; fruit 30 to 90 mm. long, 25 to 30 mm. in diameter, slightly tapered above and below with long (20 mm.) curved beak; seed 5 to 8 by 7 to 10 mm., thick and flat or occasionally hemispherical, surface rough, dull black, wingless. (Pl. 3.)

TYPE: Sierra Blanca, Tex.; flowers from cut stem, Arnold Arboretum.

RANGE: Eastern part of the Rio Grande Big Bend section of Texas in the following counties: Southern Hudspeth and Culberson; western Jeff Davis, and northwestern Presidio. Although the writer has seen a few plants of the species in the vicinity of Tesnus, eastern Brewster County, Tex., they were probably planted by early settlers of Tesnus.

The species is found on rocky and gravelly mountain slopes at approximately 3,900 to 5,000 feet elevation. On the eroding slopes and bajadas of the Sierra Diablo, Eagle, and Van Horn Mountains the species occurs in rather dense concentrations, which cover many tens of square miles. Admixed with *Yucca faxoniana* on the bajadas are *Y. torreyi* and *Y. baccata.* In several of these associations about 86 percent of the plants are *Y. faxoniana* and 14 percent *Y. torreyi,* whereas *Y. baccata* is so thinly scattered that it averages less than 1 plant per acre. These concentrations frequently have from 57 to 65 *Y. faxoniana* and from 9 to 11 *Y. torreyi* heads of leaves per acre. On the higher and more rugged mountain slopes, particularly in the Eagle Mountains, *Y. faxoniana* occurs in pure stands. Occasionally at lowest elevations, where *Y. faxoniana* approaches valley floors, it is sparsely admixed with *Y. elata.*

Yucca faxoniana usually flowers between April 15 and May 15. The species is similar to *Y. carnerosana,* and if the ranges of the two species overlapped it would be rather difficult to separate them. However, *Y. faxoniana* is distinguishable from *Y. carnerosana* by its relatively shorter, broader leaves; its

lower, decidedly broad, conoid-shaped panicle; and its relatively short perianth tube.

Apparent Hybrids of *Yucca faxoniana* and *Yucca torreyi*

Approximately 5 miles west of Allamoore, Tex., and in other places where *Yucca faxoniana* and *Y. torreyi* are admixed, apparent hybrids between the two species are quite common. The hybrids are predominantly *Y. faxoniana* in both vegetative and reproductive characters, but resemble *Y. torreyi* in one or more characters. Plants that appear to be *Y. faxoniana* frequently have more or less scabrous leaves, which occasionally are tapered from base to apex as in *Y. torreyi.* Other plants similar to *Y. faxoniana* resemble *Y. torreyi* in their short, rather thin, weak scape. Occasionally plants that appear to be otherwise typical *Y. faxoniana* have rather small, globose flowers, with the segments united only at the base, and, rarely, typical *Y. faxoniana* plants produce a long, cylindrical, short-beaked fruit resembling *Y. torreyi.* McKelvey *(24)* reported hybrids between the two species.

3. *Yucca schottii*

(Mountain or hoary yucca; locally, sword cactus)

Yucca schottii Engelm., Acad. Sci. St. Louis Trans. (1873) 3: 46. 1878.

Plant arborescent, rather symmetrical, simple, or fairly tall (1.5 to 2.0 m.), rather open clump of stems and heads of leaves, with stems contiguous at base and somewhat spreading toward top; stems commonly 2 or 3, rarely up to 6, of varying height, the older trunklike, up to 4.6 m. tall and 32 cm. in diameter, unbranched or with 2 or 3 assurgent branches; leaves numerous in terminal head, or entire stem bearing fresh leaves, the blade 40 to 90 cm. long, 2.5 to 5.5 cm. wide, divergently spreading, thin, flexible; leaf margin thin, without fibers, or with few fine fibers; scape very short; panicle mainly within foliage, but somewhat extending above, narrowly ellipsoidal, rather densely branched, very tomentose or rarely glabrous; flowers small, subglobose, white; perianth segments 20 to 35 mm. long, 8 to 15 mm. wide, broadly lanceolate; filaments 12 to 14 mm. long, slender; pistil 19 to 24 mm. long; ovary 5 to 7 mm. in diameter, abruptly tapered at apex; style about 3 mm. long; fruit 60 to 125 mm. long, 25 to 38 mm. in diameter, rounded at base, tapering at apex, commonly asymmetrical and constricted near apex; seed 5 to 8 by 7 to 10 mm., thick and flat or rarely rather hemispherical, rough, dull black, wingless. (Pls. 4 and 5.)

TYPE: Sierras west of Santa Cruz County, Ariz., Mo. Bot. Gard. No. 135693.

RANGE: Southeastern Arizona and adjacent corner of New Mexico. Along the southern boundary of Arizona and New Mexico, particularly in New Mexico, the species reaches its height of development in that the plants are usually taller, more common, and approach fairly dense concentrations.

Yucca schottii is strictly a mountainous and foothill plant, mainly occurring in oak woodlands and shady canyon slopes at 4,000 to 7,000 feet elevation.

The species is easily distinguishable by its large, broad, nonfiliferous, flexible, dark blue-green leaves. Although it is associated with *Y. arizonica, Y. elata,* and several transitional forms of *Y. baccata-Y. arizonica,* no evidence of hybridization with these plants has been found. *Y. schottii* flowers several months later than any other bacciferous yucca (July 15 to August 15), usually following the flowering season of *Y. elata.*

4. *Yucca treculeana*

(Palma-pita or de datils; locally, Spanish-bayonet or Spanish-dagger)

Yucca treculeana Carr., Rev. Hort. 1858: 580. 1858.

Yucca canaliculata Hook., Bot. Mag. 86: *pl. 5201.* 1860.
Y. longiflora Buckl., Phila. Acad. Sci. Proc. 1862: 8. 1863.
Y. argospatha Verlot, Rev. Hort. 1868: 393. 1868.
Y. aspera Engelm., Acad. Sci. St. Louis Trans. (1873) 3: 37. 1878.
Y. treculeana var. *canaliculata* (Hook.) Trel., Mo. Bot. Gard. Ann. Rpt. 13: 97. 1902.

Plant arborescent, with 1 to few stems of varying height in rather open clump; stems commonly 1 to 4 assurgently branched, 3.0 to 3.5 m. tall; leaves commonly in large, symmetrical head, or occasionally entire shoot bearing fresh leaves, the leaf blade 50 to 98 cm. long, 4 to 8 cm. wide, thick, rigid, concavo-convex, but frequently flattened; leaf margin thin, entire or with few fine, straight fibers; scape short, glabrous; panicle extending 0.5 to 0.75 percent of its length above foliage, ellipsoidal, dense; flowers small, broadly globose or hemispherical, white or lightly tinged with purple, perianth segments somewhat thickened toward base; sepals 29 to 45 (36) mm. long; 8 to 15 (11) mm. wide; petals 30 to 40 (36.5) mm. long, 11 to 21 (14.5) mm. wide; filaments 15 to 24 (18.8) mm. long; pistil 20 to 30 (27.3) mm. long; ovary 4 to 6 (5.8) mm. in diameter, apex abruptly terminating (shouldered) in style; style 1 to 5 (3) mm. long; fruit 65 to 100 mm. long, 17 to 24 mm. in diameter, cylindrical with abruptly tapered apex, symmetrical, rarely constricted; carpel-suture U-shaped, deep or frequently broad and rather flat; seed [13] 4 to 5 by 5 to 6 mm., flat, thick, rough, dull black, wingless. (Pl. 6.)

TYPE: South-central Texas and adjacent Mexico; *A. A. Trecul 1496,* Mus. d'Hist. Nat., Paris.

RANGE: The greater part of the reported distribution of *Yucca treculeana* is east of the present range of study and in Mexico. Consequently the writer has seen the species only in a limited triangular area — between Uvalde, Carrizo Springs, and Eagle Pass, Tex. In this triangle the species is thinly scattered in tall chaparral and is easily overlooked. It flowers between mid-March and early April.

Although *Y. treculeana* is a well-characterized species, it is similar to *Y. torreyi,* and variations that occur in the *Y. torreyi* so closely resemble *Y. treculeana* that it is questionable whether specific distinctions exist between the two plants. *Y. treculeana,* however, is distinguishable from typical *Y. torreyi* by its small flowers of hemispherical shape with stout ovaries and by its more symmetrical head of relatively broader, shorter leaves, which are mainly nonfiliferous.

Apparent Hybrids of *Yucca treculeana* and *Yucca torreyi*

Between *Yucca treculeana* on the east and *Y. torreyi* on the west is a comparatively large area that appears to be a transitional zone between the two species. This zone is approximately bounded by a line through Eagle Pass,

[13] Seed from single plant near Rockport, Tex.

Devils River (west of Del Rio), Rocksprings, and Uvalde, Tex. Although the plants in this zone are quite variable, their general aspect is that of *Y. torreyi.* They commonly resemble *Y. torreyi* in their long, narrow leaves, slender ovaries, and oblong tapered fruit; and they frequently resemble *Y. treculeana* in their nonfiliferous leaves and small, globose flowers. In this area McKelvey *(24, p. 115)* commonly found floral abnormalities, in addition to apparent hybrid characters, and concluded, "Some of these confusing plants may be of hybrid origin but, since the dominating influence in each cannot be estimated, all have been cited under *Y. torreyi* . . ." The writer has not found excessive vegetative or floral abnormalities in the region, and he is of the opinion that the plants are not so variable as McKelvey indicates. The two species are quite similar, and the variability that occurs is within the range to be expected of hybrids and hybrid recombinations.

5. *Yucca torreyi*

(Torrey yucca)

Leaf blade straight, rigid, glabrous or glaucescent, yellow green in color..... Y. TORREYI.

Leaf blade falcate, rather flexible, glaucous, blue green in color....Y. TORREYI, blue form.

Yucca torreyi Shafer, *in* Britton and Shafer, N. Amer. Trees, p. 157, *fig. 117.* 1908.

Yucca baccata var. *macrocarpa* Torr., *in* Emory, U. S. and Mex. Bound. Bot., p. 221. 1859.

Y. macrocarpa (Torr.) Merriam, N. Amer. Fauna 7: 358 (name only). 1893; Cov., U. S. Natl. Herbarium Contrib. 4: 202. 1893; Trel., Mo. Bot. Gard. Ann. Rpt. 13: 110. 1902. Not *Y. macrocarpa* in Engelm., 1881.

Y. torreyi f. *parviflora* McKelvey, Yuccas Southwest. U. S. 1: 112. 1938.

Plant caulescent, rather commonly arborescent, asymmetrical, or of ragged appearance, simple to rather tall, narrow, fairly dense clump of stems and heads of leaves; stems commonly 1 or 2, occasionally up to 8, of varying height, the older trunklike, rarely up to 4.3 m. tall and 30 cm. in diameter, unbranched, or rarely with 2 or 3 ascending branches; leaf head solitary or somewhat clustered; leaves few in small, terminal head or numerous in large, elongated head or cluster, the blade 30 to 103 (58.7) cm. long, 2.8 to 5.0 (3.6) cm. wide, commonly tapered from enlarged base to apex, moderately concavo-convex, or rarely somewhat flattened, thick, rigid, scabrous on both surfaces, yellowish green; leaf margin thick, with at first curly, later straight, tough fibers; scape 0 to 10 (5.2) cm. long; panicle commonly 0.1 to 0.5 of its length above foliage, or rarely entirely within, 36 to 70 (46) cm. long, ellipsoidal, dense; flowers commonly subglobose or campanulate, occasionally fully expanding, cream color to deeply tinged with dark purple; perianth segments very variable in shape and size, concave, thickened in the center from base to apex; sepals 34 to 75 (52) mm. long, 8 to 18 (14.4) mm. wide; petals 33 to 78 (50.9) mm. long, 10 to 22 (17.8) mm. wide; filaments 14 to 27 (18.5) mm. long; pistil 22 to 35 (28.2) mm. long; ovary 4 to 8 (5.9) mm. in diameter, rather stout, apex tapering into style; style 4 to 8 (5.8) mm. long; fruit 70 to 105 mm. long, 25 to 38 mm. in diameter, cylindrical or ovoid, gradually tapered from base to apex, rarely constricted; carpel suture V-shaped, deep, and narrow; seed 5 to 8 by 6 to 9 mm., flat, thick, rough, dull black, wingless. (Pl. 7.)

TYPE: Locality near Limpia Creek and near Presidio del Norte, Tex., collected by John Bigelow, the specimens apparently not now extant.

RANGE: Sierra and Dona Ana Counties, N. Mex., to the Devils River, Val Verde County, Tex., and south; but it is found as far north as Carlsbad, N. Mex. The species is usually thinly scattered on grassy and chaparral mesas and slopes at 2,000 to 5,000 feet elevation. It has not been found in dense concentration on any large area. Possibly the best and most typical plants of *Yucca torreyi* occur in Jeff Davis County and in the vicinity of Presidio, Tex. It usually flowers between late March and early May.

The species is rather variable throughout its range and blends with, or exhibits characters transitional to, *Y. treculeana* on its eastern boundary (Maverick, Kinney, Uvalde, and Edwards Counties, Tex.) and with *Y. baccata* on its western boundary (Grant, Sierra, and Dona Ana Counties, N Mex.). Probably the greatest variation in the species is in the size and shape of its flowers and in the height, size, and density of its panicles.

Yucca torreyi forma *parviflora* McKelvey is mainly characterized by its less branched panicle and its smaller, globose flowers. Since the species and form can be distinguished only by separating the extremes of the characters involved, the form is not worthy of a formal name.

Blue Form of *Yucca torreyi*

While at Black Gap in 1944, V. L. Cory[14] called the writer's attention to a new form of *Yucca torreyi*. In general, this form exhibits the distinctions that commonly characterize blue forms of fleshy-fruited yuccas. These blue form characters are as follows:

Plants mainly a denser, more confused cluster; stems more numerous and shorter; heads of leaves more asymmetrical; leaves commonly longer, always narrower, usually twisted and variously curved, always a sage or blue-green color and usually quite glaucous.

The form apparently extends north and east from Black Gap to the Pecos River basin.

In addition to typical blue-form characters, the form has smaller flowers than the species and they are usually rather heavily tinged with purple. The latter characters, however, are not necessarily distinguishing characters of the form, as fairly typical *Y. torreyi* with very small, extremely purple-tinged flowers occurs only a few miles west of Black Gap near Persimmon Gap in the Santiago Mountains.

Apparent Hybrids of *Yucca torreyi* and *Yucca baccata*

Yucca torreyi is rather easily distinguished from closely related species by its relatively ragged appearance and its comparatively long, narrow, yellowish-green leaves. However, in localities where plants of *Y. torreyi* and *Y. baccata* are rather thickly intermingled, the species are difficult to separate and apparent hybrids are quite common. In these areas tall plants with one or two vertical stems and acaulescent, fairly dense, clumped plants occur side by side. Both the tall and the clumped plants frequently have rather short, broad, dark-green leaves, and aside from height and clump habit, the majority of them

[14] See footnote 4, p. 5.

are vegetatively inseparable. Upon flowering, the tall-stemmed plants always exhibit panicles and flowers that resemble *Y. torreyi,* whereas the clumped plants exhibit either typical *Y. baccata* panicles and flowers or a panicle of *baccata* height, with an intermediate number of panicle branchlets. The flowers of the apparent hybrids are considerably larger than the average *Y. torreyi* flower, but their pistils are midway in length between the two species.

Although McKelvey (*24*) found no evidence of a crossing between *Y. torreyi* and *Y. baccata,* she observed characters that suggest a remote relationship between the species. Benson and Darrow (*3*) placed *Y. torreyi* in McKelvey's *Baccatae* series, as *Y. baccata* var. *macrocarpa* Torr., but they noted that V. L. Cory and McKelvey believed it to be a distinct species, more clearly related to *Y. treculeana.* Although the writer also holds the latter opinion, he believes that, except for *Y. schottii,* there is little difference between McKelvey's Baccatae and Treculeanae series.

Apparent hybrids involving *Y. torreyi* and other species have been discussed under *Y. carnerosana, Y. faxoniana,* and *Y. treculeana.*

Although *Y. torreyi* is commonly admixed with *Y. elata* and occasionally with *Y. thompsoniana* and *Y. reverchoni,* no evidence of hybridization with these species has been observed.

6. *Yucca schidigera*

(Mohave yucca)

Leaf blade broad, straight, very rigid, and yellow green in color.....Y. SCHIDIGERA.
Leaf blade narrow, falcate, rather flexible, and blue green in color.....
Y. SCHIDIGERA, blue form.

Yucca schidigera Roezl ex Ortgies, Gartenflora 20: 110. 1871.

Yucca californica Nutt. ex Baker, Linn. Soc. London, Jour., Bot. 18: 229 (as syn. *Y. baccata* Torr.). 1880.

Y. macrocarpa Merriam, N. Amer. Fauna 7: 358. 1893; Cov., U. S. Natl. Herbarium Contrib. 4: 202 (Calif. and Nev. plants). 1893. Not *Y. macrocarpa* Engelm. 1881.

Y. mohavensis Sarg., Gard. and Forest 9: 104. 1896.

Plant commonly fruticose, with rather symmetrical appearance, or clumped with ragged appearance; clump rather tall, broad and open, with at least several stems of equal height; stems occasionally 1 to 3, commonly 4 to 7, rarely up to 23, erect or somewhat assurgent, the older trunklike, rarely up to 2.5 m. tall and 40 cm. in diameter, simple or 1 to 4 ascending erect branches; head of leaves usually solitary, rarely clustered; leaves numerous, the blade 33 to 105 (56) cm. long, 2.5 to 5.0 cm. wide, broadest near middle, the greater part rather deeply concavo-convex, thick, very rigid, yellow green; leaf margin thick with coarse, somewhat curled fibers; scape 0 to 15 cm. long; panicle entirely within foliage, or to 0.5 of its length above, 50 to 125 cm. long, ellipsoidal or with apex flattened, densely branched and flowered; flowers globose, white or cream, commonly tinged with lavender or purple; perianth segments lanceolate or broadly lanceolate; 24 to 45 mm. long, 6 to 10 mm. wide; filaments 13 to 16 mm. long; pistil 18 to 25 mm. long; ovary 5 to 8 mm. in diameter, rather stout, tapering into style; style 1 to 2 mm. long; fruit variable, long and cylindrical, 90 to 115 mm. long, 30 to 38 mm. in diameter, with 75 percent medium-constricted, or short variable shape, but mainly tapering from swollen base to rather blunt apex 60 to 85 mm. long, 25 to 35 mm. in di-

ameter; seed 6 to 9 by 8 to 11 mm., flat, thick, rough, dull black, wingless. (Pls. 8 and 9.)

TYPE: San Diego, Calif. *Nuttall,* Gray Herbarium; type of *Yucca californica* Nutt.

RANGE: Western half of the California-Baja California border, north through San Diego, Riverside, and San Bernardino Counties, Calif., thence east and northeast, crossing the California boundary into the northwest quarter of Mohave County, Ariz., and into southern Clark County, Nev. *Y. schidigera* occurs on gravelly mountain and valley slopes of desert and chaparral, at 1,000 to 6,000 feet elevation. Throughout most of its southern California range, *Y. schidigera* is thinly scattered and rarely forms dense concentrations of large area. On the other hand, in northwestern and west-central Mojave Desert in California, in Nevada, and in the Sacramento and northern Hualpai Valleys, Ariz., it occurs in dense concentrations, which cover many tens of square miles. These stands frequently have 111 to 286 (144.12) heads of leaves per acre (pl. 8). In a letter to the writer, dated April 14, 1947, Nell Murbarger, of Costa Mesa, Calif., reported that the species occurred at 7,800 feet, above Baldwin Lake in the San Bernadino Mountains on the slope from Gold Mountain toward Lucerne Valley. The species usually flowers between April 1 and May 15.

In many parts of California *Y. schidigera* is associated with *Y. whipplei,* and, to a lesser degree, with *Y. baccata* var. *vespertina* and *Y. brevifolia.* In Arizona and Nevada it is commonly intermingled with *Y. baccata* var. *vespertina* and *Y. brevifolia.*

Blue Form of *Yucca schidigera*

Yucca schidigera is well defined and throughout most of its range exhibits little variation. A typical blue form (p. 23) centers in the Morongo Valley, San Bernardino County, Calif., and spreads eastward through Yucca Valley toward Twentynine Palms and westward through San Gorgonio Pass to the western part of the Salton Sea basin, Riverside County, Calif.

Apparent Hybrids of *Yucca schidigera* and *Yucca baccata* variety *vespertina*

In localities where *Yucca schidigera* and *Y. baccata* var. *vespertina* intermingle, unquestionable hybrids, and especially plants of hybrid derivation, are common. Such confusing plants are particularly abundant on the western bajada of the Ivanpah Mountains, San Bernardino County, Calif., and on the eastern bajada of the White Hills, Mohave County, Ariz. The majority of the characters of the hybrids are midway between the two species, although the characters of the more confusing plants vary considerably in their likeness to *Y. schidigera* or *Y. baccata* var. *vespertina.*

Comparison of *Yucca schidigera, Yucca torreyi, Yucca treculeana,* and *Yucca schottii*

Relative to *Yucca schidigera, Y. torreyi, Y. treculeana,* and *Y. schottii* McKelvey (*24, p. 66*) stated, "No distinctions in habit of the four plants holds good universally; . . . in the writer's mind, however, the impression

persists that plants of *Y. Treculeana* and *Y. Schottii* are of a more pleasing, finer (that is less coarse) appearance than plants of *Y. Torreyi* and *Y. schidigera; . . . Yucca schidigera* and *Y. Schottii* commonly produce several stems and, in the last, one stem is apt to incline outward from the base; *Y. Torreyi* and *Y. Treculeana* as a rule are single-stemmed and average taller than the other members of the group; when the leaves have fallen from the trunk of *Y. Treculeana* it looks over slender for the size of the plant." In general, this writer concurs with McKelvey, but he does not agree that *Y. schottii* produces more or shorter stems than *Y. torreyi.* In practically all yuccas, variation in height and in number of stems is quite common. Not only do variations occur in one locality, but different localities may exhibit equal, less, or greater ranges of variation, with different means. Thus, *Y. torreyi* of western Rio Grande Big Bend, Tex., would unquestionably average several feet taller and several stems less per plant than those of eastern Big Bend, Tex.; whereas *Y. schottii* in the Peloncillo Mountains and Animas Valley, N. Mex., are taller and have fewer stems than those plants of the species along the boundary of Pima-Cochise Counties, Ariz.

Yucca schidigera has more and shorter stems than *Y. torreyi,* and it is usually more fruticose or shrubby than *Y. torreyi, Y. schottii,* and *Y. treculeana.* When, rarely, *Y. schidigera* is arborescent, it is dwarf, compact, and massive, with shorter, more ascending branches than the comparable species.

7. *Yucca arizonica*

Yucca arizonica McKelvey, Arnold Arboretum Jour. 16: 270. 1935.

Yucca puberula sensu Torrey, *in* Emory, U. S. and Mex. Bound. Bot., p. 221. 1859, in part. Not Haworth 1828.

Y. brevifolia Schott. ex Torr., *in* Emory, U. S. and Mex. Bound. Bot., p. 221. 1859, in part, as synonym of *Y. puberula.* Not *Y. brevifolia* Engelm. 1871.

Y. treleasei Macbride, Gray Herbarium, Harvard Univ., Contrib. 56: 15. 1918. Not *Y. treleasei* Sprenger. 1901.

Y. baccata var. *brevifolia* Benson & Darrow, Amer. Jour. Bot. 30: 234. 1943, in part.

Plant caulescent, forming tall, rather broad, ragged, fairly dense clump; clump 1.2 to 3.7 m. in diameter, with 6 to 43 (19.95) heads of leaves at a density of 1.2 to 3.0 (1.9) leaf heads per square meter; stems, the oldest mainly assurgent or occasionally a few erect or rarely procumbent, of varying height, up to 1.0 to 2.4 (1.6) m. tall, occasionally 1 to 2 short-branched; leaf heads commonly solitary, rarely clustered; leaves rather numerous, the blade 30 to 65 (43.9) cm. long, 1.4 to 3.0 (1.9) cm. wide, slightly broadened toward middle, straight or somewhat incurved, mainly concavo-convex, somewhat flexible; leaf margin thin with fine, straight fibers; scape 10 to 32 (20.7) cm. long; panicle entirely above foliage to 0.6 (0.8) of its length above, long and narrow, 43 to 68 (55.6) cm. long, narrowly obovoid; flowers campanulate and not expanding, or very rarely somewhat subglobose and slightly expanding, white or cream, commonly tinged with purple; perianth segments lanceolate to rarely oblanceolate; sepals 55 to 122 (75.9) mm. long, 13 to 28 (21.9) mm. wide; petals 60 to 124 (75.3) mm. long, 22 to 36 (29.7) mm. wide; filaments 36 to 59 (43.3) mm. long; pistil 46 to 74 (57.7) mm. long; ovary 7 to 10 (8) mm. in diameter, narrowly ovoid, broad at base and tapering into style,

with deep carpel sutures and commonly faint anther depressions; style 4 to 10 (5.5) mm. long, tapered; fruit 70 to 120 mm. long, 20 to 30 mm. in diameter, symmetrical, broadly cylindrical or somewhat tapering; seed fairly large, flat, thick, rough, dull black, wingless. (Pl. 10.)

TYPE: Probably near Nogales, Ariz.; Mo. Bot. Gard. No. 135693.

RANGE: Southeastern half of Pima County, Ariz., east through Santa Cruz and Cochise Counties, Ariz., into the southwestern corner of Hidalgo County, N. Mex. The species occurs on gravelly and rocky hills, mountain slopes, and mesas of desert grassland and oak woodland at 3,000 to 5,700 feet elevation. In the western limits of its range, particularly on the slopes of the Baboquivari Mountains, the species occurs in fairly dense concentrations that cover many square miles. Eastward it becomes less abundant, until in the vicinity of the Arizona-New Mexico line it occurs intermittently in small patches of thinly scattered plants. The species usually flowers between April 15 and May 15.

Yucca arizonica is well defined, and in the southern part of its range exhibits little variation. Although the foliage of the species is usually somewhat blue green, about 5 percent of the plants in the northern part of the Baboquivari Mountains exhibit a more pronounced blue color and approach the typical yucca blue form (p. 23).

In the south-central and southeastern part of its range, *Y. arizonica* is somewhat admixed with *Y. schottii,* and along its northern border it is occasionally associated with *Y. elata.* In several areas north and east of the range of *Y. arizonica,* the yuccas exhibit characters that appear to be of a transitional nature between *Y. arizonica* and *Y. baccata.* These plants are discussed under *Y. baccata.*

8. *Yucca baccata*

(Datil; locally, banana yucca)

Leaf blade broad, straight, dark green, glabrous.....Y. BACCATA.
Leaf blade rather narrow, falcate, blue green, glaucous.....Y. BACCATA var. VESPERTINA.

Yucca baccata Torr., *in* Emory, U. S. and Mex. Bound. Bot., p. 221. 1859.

Plant commonly simple or clumped at ground level or rarely caulescent, with very short assurgent or procumbent stems toward center of clump; clumps 1 to 5 m. in diameter, with 6 to 70 (27.3) heads of leaves at density of 3.9 to 6.8 (5.0) leaf heads per square meter; leaf blade broadened toward middle, commonly straight or incurved, rarely outcurved, occasionally twisted, rather deeply concavo-convex, quite rigid, 30 to 71 cm. long. 3.0 to 5.5 cm. wide; leaf margin usually with coarse, short recurved fibers, occasionally with long curly fibers; scape 0 to 13 (7.0) cm. long; panicle entirely within foliage to 0.5 of its length above, obovoid or quite ellipsoidal, with oblate or acute apex, 36 to 60 (46.9) cm. long; flowers campanulate, expanding but little, pendent, white or cream, commonly tinged with purple; perianth segments lanceolate to oblanceolate; sepals 40 to 99 (66.3) mm. long, 14 to 28 (18.7) mm. wide; petals 43 to 95 (66.9) mm. long, 18 to 30 (22.6) mm. wide; filaments 24 to 40 (31.4) mm. long; pistil 38 to 74 (48.6) mm. long; ovary narrowly ovoid and tapering into style at apex, with deep carpel sutures, 7 to 10 (7.6) mm. in diameter; style 4 to 10 (6.1) mm. long, tapered; fruit 70 to 235 mm. long, 25 to 55 mm. in diameter, symmetrical, broadly cylindrical, or somewhat tapering; frequently weighing 425 to 500 gm.; seed 6 to 9 by 7 to 11 mm., flat thick, rough, dull black, wingless. (Pl. 11.)

TYPE: Hurrah Creek, Guadalupe County, N. Mex., 1853, *J. M. Bigelow;* U. S. Natl. Herbarium No. 35875.

RANGE: Eastern Mojave Desert, San Bernardino County, Calif., east through the southern tip of Nevada (Clark and Lincoln Counties); southwestern corner of Utah (Beaver, Iron, Washington, and Kane Counties); the greater part of Arizona (all except southern fourth of State); all of New Mexico; south-central and southwestern Colorado; and finally southeast through Texas to the vicinity of Shannon ranch, near Ozona, Crockett County, Tex.[15] *Yucca baccata* is usually scattered on hill and mountain slopes and plains of grassland, pinyon-juniper, and oak woodlands at 2,500 to 7,250 feet elevation. Although the species usually flowers between April 15 and June 1, flowering is frequently delayed at higher elevations. Possibly the largest and densest stand of *Y. baccata* occurs along the western bajadas of the San Andres Mountain near Rhodes Pass, Socorro County, N. Mex., and variety *vespertina* is in scattered patches on the mesa between Kingman and Peach Springs, Ariz.

Yucca baccata is frequently associated with *Y. schidigera* and *Y. torreyi* and less commonly with *Y. brevifolia, Y. faxoniana,* and possibly with *Y. treculeana* and *Y. arizonica.* In addition, it is commonly admixed with several capsular-fruited yuccas. Apparent hybrids and hybrid segregates between *Y. baccata* and *Y. torreyi* have been cited on page 23, and those between *Y. baccata* and *Y. schidigera* on page 25. Apparent hybrids between *Y. baccata* and *Y. arizonica* are discussed on page 29. A reported hybrid between *Y. baccata* and *Y. glauca* (capsular-fruited species) is discussed under *Y. glauca.*

Yucca baccata variety *vespertina*

Yucca baccata var. *vespertina* McKelvey, Yuccas Southwest. U.S. 1: 45. 1938.

TYPE: Just east of Peach Springs, Ariz., 1931, *McKelvey 2167.*

Intermingled with *Yucca baccata* in the western half of its range is the variety *vespertina,* which exhibits the typical yucca blue-form characters (p. 23). (Pls. 12 and 13.)

Yucca baccata is one of the most variable species of the indehiscent-fruited yuccas. McKelvey *(24)* described the habit of *Y. baccata (p. 30)* as, "Plant commonly simple, acaulescent, occasionally forming small open clumps with 2-6 short, procumbent stems and heads of leaves. Stems scarcely exceeding 1 m. in length, covered with dead, reflexed leaves . . . " and that of variety *vespertina (p. 45)* as, "Plant acaulescent with many short, procumbent or slightly longer, more erect stems and forming dense, confused clumps."

It is the writer's opinion that except for the confused nature of the varietal clumps, the habit of both species and variety are similar and that clumps with a few heads of leaves are more common than solitary plants. Furthermore, it is believed that *Y. baccata* rarely forms strictly aerial stems and that their formation is limited to the centers of dense clumps. Such plants as exhibit noticeably long or definite aerial stems, whether assurgent or procumbent, are found mainly — possibly only — in areas where definite stemmed species, such as

[15] Shannon ranch is considerably farther east than *Y. baccata* has previously been reported. In this vicinity, near Five Oak Draw, typical *Y. baccata* occurs on a mesa, at approximately 2,500 feet elevation. Although the writer visited only one mesa in this vicinity, it is very likely that *Y. baccata* occurs on other mesas, which are common in the region. V. L. Cory, who acted as the writer's guide to the mesa, refers to it as "Salviastrum Mesa" (*9*).

Y. schidigera, Y. torreyi, or *Y. arizonica,* occur. In the vicinity of Kingman, Mohave County, Ariz., where the ranges of *Y. baccata* var. *vespertina* and *Y. schidigera* overlap, open clumps of long-stemmed plants of *Y. baccata* var. *vespertina* are rather common; whereas, not 10 miles east, on the Haulpai Valley Mesa, the variety occurs in pure stands of dense clumped plants that are stemless or practically stemless. The same condition occurs in the Mojave Desert, Calif., and a similar behavior has been noted in the case of *Y. baccata* intermingled with *Y. torreyi* north of Las Cruces, N. Mex. Except in Mohave County, Ariz., *Y. baccata* is the only indehiscent-fruited yucca that occurs north of south-central Arizona, New Mexico, and Texas, and all plants of the species in the considerably larger northern range are usually without aerial stems.

Apparent Hybrids of *Yucca baccata* and *Yucca arizonica*

Yucca thornberi McKelvey, Arnold Arboretum Jour. 16: 268. 1935.

Yucca confinis McKelvey, Yuccas Southwest. U. S. 1: 49. 1938.
Y. baccata var. *brevifolia* Benson & Darrow, Amer. Jour. Bot. 30: 234 (in part). 1943.

It is the writer's opinion that the large area separating *Yucca baccata* on the north and east and *Y. arizonica* on the south and west is a transitional zone between the two species. This zone occurs in the bordering quarters of Graham, Pinal, and Pima Counties, Ariz., and extends east and southwest through Cochise County, Ariz., into the southwestern corner of Hidalgo County, N. Mex. The area is populated with scattered variable plants and scattered dense patches of fairly uniform yuccas. Detailed and minor studies in many localities of the area show that the yuccas are similar to *Y. baccata* or *Y. arizonica,* or are midway between the two species in varying degrees. In general the plants in the eastern part of the area resemble *Y. baccata* in clump size and density, leaf shape, and panicle shape and size; but the stems and panicle height of these plants are too tall for the species. In the central part of the area plants resemble *Y. baccata* in clump size and leaf shape; *Y. arizonica* in clump density and panicle shape and size; and are about intermediate in panicle and stem height (pl. 14). In the western part of the area the yuccas approach *Y. arizonica* in leaf shape and panicle height, but the clump size and density is more like *Y. baccata* and the stems are intermediate in height. Although the flower characters of the two species are quite similar, measurements show that the flowers in the eastern part of the zone resemble those of *Y. baccata,* and those in the western part are similar to *Y. arizonica.*

Adding to the complexity of the plants in this zone are typical blue-form characters (p. 23). This character enters the zone from Safford and spreads northwest to approximately Miami, Ariz., where it appears to reach its height. The blue-form type does not occur in the southern part of the zone. It is the writer's opinion that failure to recognize the blue-form characters has caused much of the confusion as to the taxonomic position of the yuccas in northeastern Pinal and north-central and northwestern Graham Counties, Ariz.

Under *Baccatae* McKelvey (*24*) described four species. Two of these species, *Y. baccata* and *Y. confinis,* were distinguished (*24, p. 14*) by their acaulescent habit and by the "clavate tip of filament turning at a more or less conspicuous angle to the lower portion at anthesis." The other two, *Y. arizonica* and *Y. thornberi,* were characterized by their caulescent nature and by the "clavate tip of filament little angled in relation to lower portion at anthesis."

McKelvey separated *Y. confinis* and *Y. arizonica* from *Y. baccata* and *Y. thornberi* by the ligneous inflorescences of the former. According to McKelvey the inflorescence of *Y. confinis* extended about one-half of its length above the foliage and that of *Y. arizonica* extended beyond the foliage for the greater part of its length. The inflorescences of *Y. baccata* and *Y. thornberi* were fleshy at anthesis; that of *Y. baccata* was nearly buried in the foliage; and that of *Y. thornberi* was raised above the foliage for one-third to one-half of its length.

Yucca confinis occurs in the extreme southeastern corner of Arizona and adjacent corner of New Mexico, and *Y. thornberi* occurs throughout Cochise, northeastern Pima, and southwestern Pinal Counties, Ariz. In these plants the writer has been unable to find any differences of the angle of the filament tip at anthesis and, although in several instances the inflorescence appears more ligneous than in others, in the main, woodiness is a variable character and more or less fleshy and ligneous inflorescences occur in all four species.

Aside from the presence or absence of stems, the writer has been unable to separate *Y. confinis* and *Y. thornberi.* In the type locality of *Y. confinis,* both stemmed and acaulescent plants occur side by side. Although scattered plants and patches of plants closely adhere to *Y. thornberi,* the writer is of the opinion that they, as well as the few plants adhering to *Y. confinis,* are transitional plants.

According to McKelvey (*24*), her studies indicated that in the southeastern part of the range of *Y. thornberi* the species probably hybridized with *Y. arizonica, Y. confinis,* and *Y. baccata;* whereas, in its northern distribution it might hybridize with *Y. baccata, Y. baccata* var. *vespertina,* and probably with *Y. arizonica,* although the range of *Y. arizonica* was widely separated from that of the northern range of *Y. thornberi.* Relative to this group of species McKelvey (*24, p. 63*) stated, "The flowers of all four species of the group [*Baccatae*] are very similar but marked difference of habit, of inflorescence and, to a lesser degree, of foliage distinguish them."

Benson and Darrow (*3*) included *Y. arizonica, Y. thornberi,* and *Y. confinis* in *Y. baccata* Torr. var. *brevifolia* (Schott) Benson & Darrow; whereas Kearney and Peebles (*20*) placed *Y. confinis,* along with *Y. baccata* var. *vespertina,* under *Y. baccata,* and *Y. thornberi* under *Y. arizonica.* The distinctions between *Y. baccata* and *Y. arizonica* are well marked at the extremities of their ranges, but transitional forms predominate in the area of their overlapping ranges.

9. *Yucca brevifolia*

(Joshua-tree; locally, tree-yucca, cactus-yucca, yucca-palm)

Plants solitary or rarely with 2 to 3 stems.
Stems 5 to 12 m. tall; openly branched at 2 to 3 m. above soil level..... Y. BREVIFOLIA.
Stems 3 to 6 m. tall; densely branched at 0.7 to 1.0 m. above soil level..... Y. BREVIFOLIA var. JAEGERIANA.
Plants clumped with numerous stems.....Y. BREVIFOLIA forma HERBERTII.

Yucca brevifolia Engelm. in King, U. S. Geol. Expl. 40th Par. Rpt. 5: 496. 1871.

Yucca draconis var. *arborescens* Torr., Pacific R. R. Rpt. 4:147. 1857.
Y. arborescens (Torr.) Trel., Mo. Bot. Gard. Ann. Rpt. 3: 163. 1892.

Clistoyucca arborescens (Torr.) Trel., Mo. Bot. Gard. Ann. Rpt. 13: 41. 1902.

C. brevifolia (Engelm.) Rydb., Flora Rocky Mountains and Adj. Plains, p. 170. 1917.

Plant arborescent, commonly with 1, occasionally 2 or 3 huge, trunklike stems; stems 5 to 12.5 m. tall, 0.4 to 0.8 m. in diameter, expanding rapidly to extremely large base, mainly dichotomously branched; primary branches erect-assurgent; secondary branches diffused; leaves numerous, encircling ends of branches, tapering from base to pungent apex, plano-convex or triquetrous, rigid, the blade 15 to 35 cm. long, 0.7 to 1.5 cm. wide; leaf margin thin, horny, minutely denticulate; scape 0 to 8 cm. long; panicle 25 to 55 cm. long, ellipsoidal or ovoid, very dense; flowers oblate-ellipsoidal to globose, scarcely expanding, greenish white; perianth segments thick and succulent, oblong to lanceolate with incurved apex, the outer series scarcely expanding, the inner series expanding about half their length; sepals 27 to 59 (45.9) mm. long, 11 to 20 (18.8) mm. wide; petals 26 to 65 (43.9) mm. long, 13 to 22 (14.4) mm. wide; pistil 20 to 34 (27.5) mm. long; ovary 8 to 11 (9.6) mm. in diameter, tapering from base to apex, pale green, with shallow carpel sutures and deep anther depressions; style 0 to 5 mm. long; filaments 10 to 20 (11.6) mm. long, stout, stiff; fruit 60 to 85 mm. long, 30 to 45 mm. in diameter, dry and rather spongy, ellipsoidal, commonly with deep fissures at carpel sutures; seed 8 to 11 by 9 to 12 mm., flat, slightly thickened, smooth or rarely somewhat wrinkled; dull black, and wingless. (Pl. 15.)

TYPE: Date Creek, Yuma County, Ariz., 1869, with Parry note attached, *Palmer,* Mo. Bot. Gard. Nos. 135643, 135646.

RANGE: California — from the Little San Bernardino, Cottonwood, and Iron Mountains, Riverside and San Bernardino Counties, northwest through the Mojave Desert to Owens Valley, Inyo County; Nevada — from Esmeralda County east and southeast through Nye, Lincoln, and Clark Counties; Utah — southwestern Washington County; and Arizona — western Mohave, southwestern Yavapai and northern Yuma Counties.

Yucca brevifolia, its variety, and its form occur on desert plains and alluvial fans at 1,500 to 6,000 feet elevation. At the lower elevations it is commonly associated with the creosotebush, and at higher elevations with junipers, oaks, and pinyon pines. In a letter Nell Murbarger (p. 25) stated that on the slopes of Gold Mountain, San Bernardino Mountains, *Y. brevifolia* was not uncommon among pinyon pine and juniper at 6,500 feet elevation. Although the species was frequently scattered, it, like other yuccas, commonly occurred in definite belts and communities. Photographs supplied by Miss Murbarger indicate that the plants at the high elevation are forma *herbertii. Y. brevifolia* and its variety are the most imposing yuccas in the Southwest and rank with the giant cactus (*Cereus giganteus*) as a symbol of the desert. Individual plants 15 to 18 m. or more tall have been reported.

Yucca brevifolia variety *jaegeriana*

Yucca brevifolia var. *jaegeriana* McKelvey, Arnold Arboretum Jour. 16: 269. 1935.

Yucca brevifolia var. *wolfei* Jones, West. Bot. Contrib. 18: 125. 1935.

Variety *jaegeriana* differs from the species in its smaller growth habit, 3 to

6 m. tall; more numerous, shorter, and rarely spreading branches that develop closer to the ground; and shorter leaves, 10 to 20 cm. long. The dwarf, compact nature of the variety is unique and attractive; in many respects it gives the impression of an oriental dwarf tree. (Pls. 16 and 17.)

TYPE: Vicinity of the Shadow Mountains, San Bernardino County, Calif., about 1,200 m., April 30, 1932, *McKelvey 2732,* Arnold Arboretum.

RANGE: From Shadow, Kingston, Clark, and New York Mountains, northeastern San Bernardino County, Calif., east and northeast across Clark County, Nev., into Washington County, Utah, and Mohave County, Ariz.

Wolf (*35, p. 7*), Munz (*27*), and others called attention to two large forests of variety *jaegeriana* that far surpassed any other yucca concentration in the southwestern United States. One of these concentrations lies between the southern extension of the Shadow Mountains and the Ivanpah Mountains and extends west to Halloran Springs and east into the Ivanpah Valley about Cima, Calif. The other is southeast of the preceding concentration, extending from the western side of the New York Mountains eastward through Lanfair Valley into the southern end of the McCullough Mountains, Nev. (pl. 17).

Yucca brevifolia forma *herbertii*

Yucca brevifolia forma *herbertii,* forma nov. [16]

Forma *herbertii* differs from *Yucca brevifolia* and its variety *jaegeriana* in its extremely large, dense clump of many shoots and heads of leaves. A single clump frequently covers an area 8 m. in diameter, with 30 to 40 trunklike stems. In the majority of plants, the older stems are toward the center of the clump and are from 3 to 5 m. tall. Such stems bear from 4 to 12 short branches, and they frequently recline on adjacent stems, as if too weak to stand. (Pl. 18.)

TYPE: West end of Antelope Valley, Los Angeles County, 21 miles west of Lancaster, Calif., elevation 2,940 feet, *J. M. Webber,* April 11, 1946, No. 424, Univ. Calif. Herbarium; cotype No. 423, U. S. Dept. Agr., Plant Indus. Herbarium.

RANGE: Extending from type locality northwest along the southern and western slopes of the Tehachapi Mountains to at least Monolith, Calif.

The form is dedicated to the writer's father, Herbert John Webber, who noticed the distinguishing characteristics of the form.

DEHISCENT-FRUITED YUCCAS

10. *Yucca whipplei*

(Our-Lord's-Candle, chaparral yucca, quixote yucca)

Plant simple, solitary, dying when fruit has formed.....Y. WHIPPLEI.
Plant caespitose or forming a large, fairly open clump, fruiting for many years.
  Plant caespitose, very dense and compact.
    Secondary rosettes formed in seedling stage and in axis of leaves, usually a large clump of many rosettes, and several flower stalks each spring.....
      Y. WHIPPLEI var. CAESPITOSA.

[16] Latin description translated from English by John Thomas Howell, California Academy of Sciences:

Planta globum densum usque ad 150 sq. m. tegentem faciens, 7.5 fasciculis foliorum et 1.8 caudicibus basilaribus in 1 sq. m., caulibus usque ad 3.0 — 6.5 m. (4.0. m.) altis.

Secondary rosettes formed after flowering near base of old flower stalks, usually a comparatively small clump and only one flower stalk each spring. Y. WHIPPLEI var. INTERMEDIA.

Plant a large, fairly open clump; secondary rosettes mainly developed from rhizomes ..... Y. WHIPPLEI var. PERCURSA.

Yucca whipplei Torr., *in* Emory, U. S. and Mex. Bound. Bot., p. 222. 1859.

?Yucca californica Groenland, Rev. Hort. (Paris), p. 434. Aug. 16, 1858.
Y. graminifolia Wood, Acad. Nat. Sci. Phila. Proc., p. 167. 1868.
Hesperoyucca whipplei Baker, Kew Roy. Bot. Gard. Bul. Misc. Inform. 5: 8. 1892.
Yucca whipplei var. *parishii* Jones, West. Bot. Contrib. 15: 59. 1929.
Y. whipplei subsp. *typica* Haines, Madroño 6: 43. 1941.
Y. whipplei subsp. *parishii* Haines, Madroño, loc. cit.
Y. newberryi McKelvey, Yuccas Southwest. U. S. 2: 49. 1947.
Y. whipplei McKelvey, Yuccas Southwest. U. S. 2: 42. 1947. (Solitary plants.)

Plant acaulescent, simple, dying after fruit has been formed; leaf blade 25 to 115 (65) cm. long, 5 to 35 (18) mm. wide, linear or rarely narrowly lanceolate, plano-convex to subtriquetrous, or keeled on both surfaces, finely striate, rigid and swordlike to flexible and frequently falcate, commonly glaucous; leaf margin thin, corneous, more or less serrulate; scape 0.9 to 4.5 m. tall; panicle 0.5 to 3.5 (1.5) m. tall; 0.2 to 0.9 (0.45) m. in diameter, cylindrical or somewhat slender-ellipsoidal, densely flowered; flowers usually expanding broadly, white or tinged with purple; perianth segments broadly lanceolate, the sepals and petals nearly equal in size, 30 to 65 mm. long, 8 to 25 mm. wide; filaments usually exceeding the pistil, not united at base and without well-differentiated clavate tip, 8 to 20 mm. long; ovary stout, 6 to 10 mm. in diameter, 8 to 12 mm. long, oblately ellipsoidal or obovoid, terminating abruptly with squarish shoulders, often depressed at apex; style short and slender; stigma capitate, with elongated, translucent papillae; capsule 30 to 50 mm. long, 15 to 30 mm. in diameter, obovoid, acute or short-mucronate, rarely constricted, dehiscence loculicidal by splitting along secondary fissures of the capsule; seed 6 to 7 by 8 mm., flat, thin, smooth, dull black, without marginal wing. (Pl. 19.)

TYPE: San Pasqual, San Diego County, Calif., *Schott,* Torrey Herbarium, N. Y. Bot. Gard.

RANGE: Baja California boundary, northwest through San Diego, Orange, Riverside, San Bernardino, Los Angeles, Ventura, Santa Barbara, Kern, San Luis Obispo, and Tulare Counties to south-central Monterey and southeastern San Benito Counties, Calif. In northwestern Arizona, it occurs in scattered patches along the Colorado River from approximately Pierce Ferry east to the mouth of Diamond Creek, Mohave County. Although the species is usually scattered on mountain slopes and mesas of chamisal, chaparral, and desert woodlands from near sea level to 4,500 feet elevation, it occasionally extends well into the montane forest up to 7,500 feet. The species usually flowers between mid-March and the end of May.

Yucca whipplei variety *caespitosa*

Yucca whipplei var. *caespitosa* Jones, West. Bot. Contrib. 15: 59. 1929.

Yucca whipplei subsp. *caespitosa* Haines, Madroño 6: 43. 1942.
Y. whipplei McKelvey, Yuccas Southwest. U. S. 2: 24 (clumped plants, in part). 1947.

Variety *caespitosa* differs from the species in the following respects: It is compound and ultimately forms a large, dense clump of numerous, clustered rosettes; it lives for many years and usually produces several flower stalks each spring; and its leaf blade is slightly shorter (58 mm.), more glaucous, and quite rigid. When variety *caespitosa* seedlings are 6 months to 2 years old, buds are formed in the axils of the leaves. These buds soon give rise to numerous secondary rosettes. Development of the secondary rosettes is accompanied by the formation of short, lobelike stems or branches. The branches are always on the surface of the ground, and the stem cannot be observed unless the rosettes are split open or the leaves removed.

TYPE: Cactus Flat in Cushenbury Canyon, San Bernardino County, Calif., *M. E. Jones,* May 12, 1926; Pomona College No. 122326, California Acad. Sci. No. 150109.

RANGE: Southern and western slopes of the Mojave Desert, from the vicinity of Baldwin Lake, San Bernardino County, to the region of Walker Pass, northwestern Kern County, Calif. It is found in desert juniper woodlands and shrubs at 1,800 to 4,000 feet elevation.

Yucca whipplei variety *intermedia*

Yucca whipplei var. *intermedia* (Haines) comb. nov.

Yucca whipplei subsp. *intermedia* Haines, Madroño 6: 43. 1942.
Y. whipplei var. *caespitosa* Jones, West. Bot. Contrib. 15: 59 (in part). 1929.
Y. whipplei McKelvey, Yuccas Southwest. U. S. 2: 24 (clumped plants, in part). 1947.

Variety *intermedia* is similar to *caespitosa* in that it lives for many years and forms a dense clump of rosettes. The clumps of *intermedia,* however, are comparatively small, and the plant rarely forms more than one inflorescence in a single season. Although the leaf blade is similar in size to that of the species, it is possibly somewhat more rigid and glaucous than that of variety *caespitosa.* In variety *intermedia* secondary rosettes are formed near the base of old flower stalks from apparently adventitious axillary buds, which develop below the dying portion of rosette and flowering stalk. Following secondary rosette formation, short, lateral branches are formed similar to those in variety *caespitosa.* In variety *intermedia,* however, the old mother rosette rarely produces more than one or two secondary rosettes and branches.

TYPE: Malibu Lake, Santa Monica Mountains, *A. L. Haines,* Univ. Calif., Los Angeles Herbarium.

RANGE: Santa Monica and Santa Susana Mountains of Los Angeles and Ventura Counties, Calif., from near sea level to 2,000 feet elevation.

Yucca whipplei variety *percursa*

Yucca whipplei var. *percursa* (Haines) comb. nov.

Yucca whipplei subsp. *percursa* Haines, Madroño 6: 43. 1942.
Y. whipplei McKelvey, Yuccas Southwest. U. S. 2: 24 (clumped plants, in part). 1947.

Variety *percursa* is similar to the preceding two varieties in that upon reaching maturity it forms clumps, flowers, and fruits for many years. Variety *percursa* differs from the other varieties, however, in that its clumps are larger and rather open and composed of distinct, scattered rosettes and rosette clusters. It differs from all other members of the species in that its leaf blades are shorter (25 to 90 (48) mm.) and somewhat more rigid. In variety *percursa,* secondary rosettes are mainly of rhizomatous origin, which results in a rather open, large clump. Following flowering, however, the secondary rosettes occasionally produce adventitious axillary rosettes, which add to the density and confused nature of the clump.

TYPE: Cochuma Mountain in San Rafael Mountains of Santa Barbara County, Calif., *A. L. Haines,* Univ. Calif., Los Angeles Herbarium.

RANGE: San Rafael, Santa Ynez, and Santa Lucia Mountains of Santa Barbara and Monterey Counties, Calif., on mountain slopes and mesas of sage and chaparral, from near sea level to about 2,000 feet elevation.

Discussion of Varietal Forms

In a study of variations and growth habits of *Yucca whipplei,* Haines (*15*) segregated five subspecies. Three of these subspecies were the varieties described above. Haines fourth and fifth subspecies, *typica* and *parishii* (var. *parishii* Jones), respectively, were segregated from the species as here defined by the following characters: For subspecies *typica* flower stalk 5 to 13 feet high, 1 to 4.5 inches in diameter; panicle 1.5 to 7 feet long, 0.5 to 2 feet in diameter; and for subspecies *parishii* flower stalk 7 to 20 feet high, 1.5 to 6 inches in diameter; panicle 3 to 11.5 feet long, 1 to 3 feet in diameter. According to Haines, the five types were possibly geographic races, segregated by geographic barriers; he thus treated them as subspecies.

McKelvey (*25*) called attention to the fact that, possibly owing to environmental differences, all yuccas are quite variable in size, and she cited several localities in which the size relationships of subspecies *parishii* and subspecies *typica* do not exist. She therefore concluded that the segregation of these two types was unjustified. The field findings of the writer confirm those of McKelvey.

McKelvey believed that three of Haines' attributes of subspecies *intermedia* suggested an intermingling of a caespitose and a monocarpic form. These characteristics *(25, p. 39)* were as follows: (1) ". . . branching 'by means of axillary buds to form short lateral branchlets' (*intermedia*) appears intermediate between branching 'on the surface of the ground' (*caespitosa*) and non-branching (*typica* and *parishii*)"; (2) *intermedia,* a caespitose form, is occasionally solitary; and (3) *intermedia,* with a group of rosettes, forms only one inflorescence a season. McKelvey concluded, "It seems probable . . . that, over the entire area between these northern [*caespitosa*] and southern [*typica* and *parishii*] forms, and extending into the ranges of each, a race of unstable and intermediate plants should exist."

It is the writer's opinion that there is little or no relationship between the methods of branching in varieties *caespitosa* and *intermedia.* The branching of variety *intermedia* appears to be purely adventitious, possibly stimulated by flowering. The method is characteristic of the majority of yuccas, and it is not uncommon in long-stemmed forms to find the branches (or new leaf heads) developing below the fresh leaves of the old dying leaf head and flower stalk. Furthermore, occasionally such forms fail to flower, in which case no secondary leaf heads or branches are formed. In variety *caespitosa,* the branches are formed from buds developed at a definite time and place. In the majority of plants of variety *caespitosa* and variety *intermedia* there is no appreciable difference in height of branching. Such height differences as do occur are undoubtedly caused by the relative age and crowded condition of the plant. The secondary rosettes of mother-seedling rosettes of both varieties are approximately at soil level.

Haines' statement that variety *intermedia* was occasionally solitary probably indicated that there was hybridization, but not necessarily that all plants of *Y. whipplei* var. *intermedia* were hybrids nor that variety *caespitosa* was involved in its production. If variety *intermedia* were a hybrid between variety *caespitosa* and a solitary form, one would expect *caespitosa* to occur as well as the solitary form. That variety *intermedia* is not a hybrid is indicated by its occurrence in pure concentrations.

Although the writer is unable to suggest why *Y. whipplei* var. *intermedia* forms only one inflorescence a year, he does not believe it indicates hybridization.

Since McKelvey's knowledge of varieties *percursa* and *caespitosa* was mainly limited to herbarium material, she considered herself unqualified to express an opinion upon their distinctions. She pointed out, however, that field and garden experience suggested that soil texture (rocky or open) might have some bearing upon the length of offset and, hence, density of plant. Although such response to soil texture is unquestionable, nursery and field evidence indicates that the methods of branching and the main characteristics of the branches are inherited.

Haines (*15, p. 36*) stated: "The only points at which any of these races are known to merge and exhibit intermediates lies in the Cajon Pass area where hybridization is apparently frequent between the solitary montane form and the caespitose desert form." In this region and along the southwestern slopes of the San Gabriel Mountains, the plants appear to form a variable group of intermingled caespitose and monocarpic forms. Although typical *Y. whipplei* and variety *caespitosa* occur, intermediate plants are more common. The intermediate plants are much more vigorous than either *Y. whipplei* or its variety *caespitosa* and exhibit fewer rosettes than *caespitosa.* Their leaves are larger, stiffer, and more glaucous than either the species or variety. The most distinctive character of these apparent hybrids are the occasional occurrence of short rhizomes in older dense plants similar to those of variety *percursa,* and of short (8 to 20 cm.) thin-stemmed axillary rosettes in comparatively young seedlings. The behavior of nursery seedlings from the Cajon Pass area verifies the hybrid nature of these plants.

Relative to the capsules of *Y. whipplei* and *Y. peninsularis* McKelvey (a Baja California species), McKelvey (*25, p. 22*) stated that they show " a well-developed false septum which consists of a conspicuous fibrous fringe borne on the midrib of the carpel and which projects well into the cell-cavity and has its distal margin lying between two conspicuous tough plates of tissue that

appear to be laminar outgrowths from the two placental lines on the inner angle of the carpel; in the open capsule these two plates give a 'winged' appearance to the placenta." In a solitary form of *Y. whipplei* in northwestern Arizona, McKelvey found that the placental wing was weak or possibly rudimentary. McKelvey also found that these plants resembled the caespitose, perennial form of *Y. whipplei* in foliage, in fragility of inflorescence, and in small fragile, lightweight, eventually widespreading capsule with pale tan epidermis. The rudimentary nature of the placental wing and the monocarpic behavior in conjunction with the characteristic caespitose form led McKelvey to segregate these plants from *Y. whipplei* as *Y. newberryi*.

Yucca newberryi (*25*) is reported on the southern side of the Colorado River from approximately the west end of the Grand Canyon to Lake Mead, Ariz. On several occasions the writer has seen a few scattered plants of the form approximately 3 miles northeast of Pierces Ferry and in the vicinity of New Water Point. Since, however, he has not seen the plants in flower nor carefully observed their capsular structure, he is unqualified to express an opinion upon these organs. It is the writer's impression, however, that *Y. newberryi* is separated on too variable and minor characters. In the vicinity of Pierces Ferry, the leaves of *Y. whipplei* average about 65 cm. long, 3 cm. wide, and are subtriquetrous or somewhat 4-sided(keeled distinctly below and slightly above); the inflorescence (old) is approximately 3 m. tall; and the capsules rather small. All of these characters are well within the range of variations exhibited by *Y. whipplei*. In the majority of yuccas, capsule texture, color, and degree of expansion, as well as size and shape, are very variable. The capsules of *Y. elata* are fragile and papery in the vicinity of Salome, Ariz.; are white and comparatively smooth in White Sands National Monument, N. Mex., and the dorsal suture at the apex of the capsule commonly separates, forming a pocket, in the vicinity of Pecos, Tex. In the vicinity of Tucumcari, N. Mex., the capsules of *Y. glauca* allies vary from those that never open or expand to ones that expand fully or nearly flat.

Although members of the *Y. whipplei* alliance are associated with, or found in close proximity to *Y. brevifolia, Y. schidigera,* and *Y. baccata,* no evidence of hybrids between it and these species has been found.

Among our southwestern yuccas, members of the *Y. whipplei* group are unusual in several ways. It is the only species that produces a definite bulb (seedling stage) or that has a capitate stigma and strictly loculicidally dehiscent capsules. The inflorescence of *Y. whipplei* in several parts of its range, mainly at higher elevations, is by far the largest and most attractive of yuccas, and its flowers are much more fragrant than those of *Y. carnerosana* or *Y. faxoniana,* the only other fragrant yuccas in the Southwest. *Y. whipplei* is the only southwestern yucca that produces a single rosette, a single inflorescence, and then dies. Evidence indicates that the species completes its entire life in 4 to 6 years, whereas all other yuccas live indefinitely and usually flower each year after reaching maturity. Furthermore, the failure of *Y. whipplei* to produce secondary rosettes means that it is the only yucca that depends entirely upon seed for propagation and distribution. The variety *caespitosa* is the only yucca that produces axillary rosettes at a definite period of life and in a definite axil. As the axillary rosettes are a method of propagation, the *Y. whipplei* group is the only species group having three distinct types of propagation; that is, seed, axillary bulbose-rosettes, and rhizomatous-rosettes.

11. *Yucca rostrata*

(Big Bend yucca)

Yucca rostrata Engelm. ex Trel., Mo. Bot. Gard. Ann. Rpt. 13: 68. 1902.

Yucca rostrata f. *integra* Trel., Mo. Bot. Gard. Ann. Rpt. 22: 102. 1911.

Plant arborescent, rather symmetrical, with 1 to 5 (1.9) shoots; stem 1 to 4.5 (2.3) m. tall, 18 to 32 (27.2) cm. in diameter, trunklike, erect, with 0 to 3 (1.5) short assurgent branches toward the top; stem and branches covered with reflexed dead leaves; leaf head symmetrical, large and elongated; leaves numerous, the blade 42 to 61 (49.5) cm. long, 12 to 17 (14) mm. wide, linear, or somewhat broader toward center, flat, concavo-convex or keeled on both surfaces, striate, thin, flexible, glaucous, pungent; leaf margin corneous, yellow, hyaline, minutely denticulate; scape 30 to 70 (54) cm. long, stout, glabrous or evanescently pubescent; panicle 0 to 20 (15.6) cm. above foliage, 35 to 70 (56.6) cm. long, narrowly ellipsoidal to somewhat ovoid, densely flowered, with 28 to 40 branchlets, 2 to 35 cm. long; flowers white, globose to campanulate, fully expanding at anthesis, with umbonate base; perianth segments narrowly oblong, sharply acuminate, conspicuously veined; sepals 42 to 47 (44) mm. long, 12 to 16 (14) mm. wide; petals 42 to 50 (45.2) mm. long, 11 to 20 (15.3) mm. wide; filaments 17 to 20 (19) mm. long, with fairly erect clavate tip, pistil 25 to 35 (27.5) mm. long; ovary 4 to 6 (5) mm. in diameter, usually tapering into style, or rarely somewhat abruptly terminating in style; style 6 to 14 (8) mm. long, attenuate, white; capsule 35 to 70 mm. long, 18 to 25 mm. in diameter, ellipsoidal or somewhat ovoid, with long-attenuate or rarely short-attenuate beak and obconical pedicel, rarely constricted; beak of dry capsule flaring, with long valve points outcurved and twisted; seed 4 to 5 by 6 to 7 mm., flat, thin, dull black, without marginal wing. (Pl. 20.)

TYPE: Monclova, Mexico, *E. Palmer 1880;* Mo. Bot. Gard. No. 148694.

RANGE: Northern Mexico, from northern Chihuahua to the Sabinas Valley in eastern Cochuila. In the United States it is limited to south-central and southeastern Brewster County, Tex. Although the species is usually rather thinly scattered on mountain slopes and bajadas at 2,400 feet elevation, it occasionally occurs in quite dense concentrations of several acres in area. The species usually flowers between March and April.

Yucca rostrata is one of our most attractive and graceful yuccas. The heads of leaves are large, very symmetrical, and vary from nearly globose to cylindrical in shape. Its numerous, rather glaucous leaves, frequently twisted so that the upper and lower side are reversed toward the middle, radiate from the head center. The old, dead leaves closely reflexed against the stem in definite growth cycles form a persistent straw-colored, thatchlike covering over the majority of the stem.

Although the leaf margins of most plants bear minute teeth, the character appears somewhat unstable. Rarely, the denticulations are lacking. The entirely smooth-edged plants have been referred to as *Y. rostrata* forma *integra* Trel.

Yucca rostrata is commonly admixed with *Y. carnerosana* and *Y. torreyi,* and possibly in some sections of its range may be associated with *Y. elata.* In habitat *Y. rostrata* and *Y. elata* are quite similar, and at a distance they are readily mistaken for one another. No evidence of hybridization between *Y. rostrata* and other yuccas has been observed.

12. *Yucca thompsoniana*

(Trans-Pecos yucca)

Yucca thompsoniana Trel., Mo. Bot. Gard. Ann. Rpt. 22: 101. 1911.

Yucca rostrata Engelm. ex Trel., Mo. Bot. Gard. Ann. Rpt. 13: 68 (in part). 1902.

Plant arborescent, frequently asymmetrical or rarely symmetrical, with 1 to 3 (1.3) shoots, stems 0.7 to 2.6 (1.4) m. tall, 12 to 15 (14) cm. in diameter, trunklike, erect with comparatively long, assurgent or diffused branches; leaf heads frequently asymmetrical, rather small and composed of comparatively few leaves; leaf blade 18 to 30 (21.7) cm. long, 7 to 12 (8.3) mm. wide, linear or somewhat broader toward center, flat or concavo-convex to plano-keeled, striate, thin and flexible; leaf margin corneous, yellow or brownish, minutely denticulate; scape 38 to 68 (55.6) cm. long, stout, glabrous or evanescently pubescent; panicle 11 to 19 (15.6) cm. above foliage, 52 to 82 cm. long, narrowly ellipsoidal to somewhat ovoid, densely flowered with 20 to 34 branchlets, 2 to 22 cm. long (average of 10 longest, 17 cm.); flowers white, globose to campanulate, spreading flat at anthesis, with umbonate base; perianth segments narrowly oblong, sharply acuminate, conspicuously veined; sepals 35 to 67 (46.9) mm. long, 12 to 26 (15.9) mm. wide; petals 40 to 66 (49.9) mm. long, 11 to 35 (19.8) mm. wide; filaments 17 to 33 (23.0) mm. long, with fairly erect clavate tip; pistil 25 to 38 (31.1) mm. long; ovary 4 to 6 (4.4) mm. in diameter, slender, usually tapering into style, or rarely somewhat abruptly terminating in style; style 6 to 18 (14) mm. long, attenuate, white; capsule 35 to 70 mm. long, 20 to 25 mm. in diameter, ellipsoidal or somewhat ovoid, with long attenuate or rarely short-attenuate beak and obconical pedicel, rarely constricted, beak of dry capsule flaring, with long reflexed, often twisted, valve points; seed 5 to 6 by 6 to 7 mm., flat, thin, dull black, without marginal wing. (Pl. 21.)

TYPE: Bufatello, near Presidio del Norte, along the Rio Grande, Mexico; J. *M. Biglow,* August 1852, N. Y. Bot. Gard.

RANGE: North and central Brewster County, east-central and southern Pecos County, throughout Terrell County, and western half of Crockett County, Tex. The species is usually thinly scattered on exposed rocky knolls and slopes at 900 to 4,400 feet elevation. Fairly good, but small concentrations occur 16 miles east of Marathon, Tex., in the State game preserve; 28 miles south of Marathon, in the Texas Rio Grande Big Bend area; and 10 to 12 miles east of Fort Stockton, Tex. The species usually flowers between April 15 and May 30.

In many respects *Yucca thompsoniana* appears to be a dwarf form of *Y. rostrata,* which occurs slightly south and southwest of its range. It cannot be considered a nanate form of *Y. rostrata,* however, since several of its organs are equal in size or larger than those of *Y. rostrata.* Its few branches are longer and more diffused. Frequently in old plants the main stem (trunk) appears too slender and weak to support the relatively long spreading branches, and the branches themselves often look as if they would fall of their own weight. The leaves and leaf heads of *Y. thompsoniana* are much smaller than those of *Y. rostrata,* and the older heads of *Y. thompsoniana* are frequently ragged in appearance. The inflorescences and flowers of both species are about equal in size.

On several occasions it has been brought to the writer's attention that the persistent old leaves, which cover the majority of stems of *Y. rostrata,* may be a delimiting character, aiding in separating *Y. rostrata* and *Y. thompsoniana.* It is his opinion that this feature is characteristic of both species. In the majority of cases *Y. rostrata* is well protected from wind erosion by mountains and fairly heavy growths of other plants, but *Y. thompsoniana* is usually exposed on more or less gentle slopes, which have very scanty vegetation as a result of sheep grazing. Consequently, the majority of *Y. rostrata* stems are covered with a thatchlike covering of dried-out leaves, whereas the dead leaves of *Y. thompsoniana* are usually worn away by erosion. Protected plants of both forms exhibit persistent leaves, which completely cover the stems.

Scattered on a hillside, 2 miles south of Leon Powell Oil Field, northwest of Ozona, Crockett County, Tex., are small weak yuccas that resemble *Y. thompsoniana.* The plants have 1 to 4 stems, which, upon reaching 0.6 to 1.0 m. tall, bend to the ground, as if they can no longer support their weight. Decumbent stems up to 1.5 m. long are not uncommon. The plants exhibit very little clumping, and branching is mainly well above the ground. The writer has not seen either inflorescence or flowers of these plants. As the general habit of these plants differs considerably from that of the apparent hybrids discussed below, they are very likely dwarf or weak plants of *Y. thompsoniana* in its extreme north and east range.

Apparent Hybrids of *Yucca thompsoniana* and *Yucca reverchoni*

In the vicinity of Bakersfield and south toward Sanderson, Tex., apparent hybrids between *Yucca thompsoniana* and *Y. reverchoni* are common. These plants resemble *Y. thompsoniana* in their rather tall (0.5 to 1.0 m.), branched stems, and long (1.0 to 1.3 m.) flowering stalk. They resemble *Y. reverchoni* in their decidedly clumped habit and narrow panicle. The clumps are from 1.0 to 1.8 m. tall, of approximately the same diameter, and are composed of 7 to 20 heads of leaves, which are equally derived from subterranean and aerial stems. The writer has not seen the flowers of these plants.

Yucca thompsoniana is frequently associated with *Y. torreyi,* occasionally with *Y. baccata* and *Y. reverchoni,* and rarely with *Y. elata.* The writer has not found it admixed with *Y. rostrata,* which grows somewhat farther south. No further evidence of hybrids between *Y. thompsoniana* and other yuccas has been observed.

13. *Yucca rupicola*

Yucca rupicola Scheele, Linnaea 23: 143. 1850.

Yucca rupicola tortifolia Engelm., Acad. Sci. St. Louis. Trans. 3: 49. 1878.

Y. rupicola Trel., Mo. Bot. Gard. Ann. Rpt. 13: 67 (in part). 1902.

Plant acaulescent, solitary but soon becoming an open clump of scattered leaf heads; clump 1 to 2 sq. m. in area, with 6 to 15 heads of leaves; leaf heads large, spreading, with few leaves; leaf blade 30 to 58 (43.3) cm. long, 20 to 40 (30) mm. wide, very broad toward middle, concaved or flat, but oblique and undulate or twisted, slightly striate, flaccid, dark green, pungent; leaf margin hyaline reddish brown or occasionally yellow, minutely denticulate; scape

36 to 152 (89.9) cm. long, slender, 15 to 20 mm. in diameter; glabrous to lightly floccose; panicle 24 to 48 (44.4) cm. above foliage, 31 to 100 (59.5) cm. long, narrowly ovoid or narrowly pyramidal, few-flowered, with 8 to 16 branchlets; branchlet 1 to 13 cm. long (the longest, 6 to 13 cm.); flowers mainly campanulate, pendent, and expanding but little, rarely somewhat globose and open; white or greenish white; perianth segments ovate, sharply acuminate; sepals 38 to 68 (50.1) mm. long; 15 to 24 (18.8) mm. wide; petals 38 to 69 (51.2) mm. long. 19 to 30 (24.5) mm. wide; filaments 18 to 32 (25.9) mm. long; pistil 29 to 45 (40.3) mm. long; ovary 4 to 6 (4.9) mm. in diameter, tapering into style or somewhat abruptly terminating in style; style 12 to 20 (16.1) mm. long, attenuate, white or greenish; capsule 38 to 54 mm. long, 20 to 30 mm. in diameter, ellipsoidal or somewhat cylindrical with long-attenuate, or short-attenuate beak and obconical pedicel, rarely constricted; beak of dry capsule flaring with valve points generally outcurved and twisted; seed 6 to 8 by 7 to 8 mm., flat, thin, dull black, without or with very narrow marginal wing. (Pl. 22.)

TYPE: South-central Texas, *Lindheimer,* 1845, *Trecul,* 1848-49.

RANGE: Extending from Palo Pinto and Tarrant Counties, Tex., southwest to the Pecos and Rio Grande. It occurs on limestone ledges and on grass-covered plains of dense brush and open woodlands at 1,500 to 2,900 feet elevation. The plants are thinly scattered and only rarely occur in small patches. The writer's studies of the species were made in the vicinities of Junction, Kimble County, Kerrville, Kerr County, and Fredericksburg, Gillespie County, Tex., where it occurs abundantly. The majority of its reported southwestern range is occupied by apparent hybrids between the species and *Yucca reverchoni.* It flowers between mid-May and mid-June.

Trelease (*31*) suggested the name *Y. rupicola edentata* for a smooth-edged, or entire, leaf form of *Y. rupicola* collected at Cedar Hill, Tex., by Julien Reverchon, June 1903. The writer has not found any entire-leaved forms of the species.

McKelvey (*25, p. 15*) described *Y. rupicola* as "Plants with single head of leaves or in small clump with 2-6 heads; matured leaf-blade twisted, very concave . . . , with wavy, dark orange-red or red-brown margins, . . . " and gives the range of the species as "central Texas; especially prevalent over the eastern end of the Edwards Plateau . . . " North and somewhat east of the latter range, McKelvey segregated *Y. pallida,* mainly by its: "Plants usually with 10-30 heads of leaves in one clump; mature leaf-blade straight, flat except for 1.3-2.5 cm. below tip . . . , with flat, bright yellow margins . . . " Although the range of *Y. pallida* is mainly east of this yucca survey, the writer found *Y. rupicola* on the Edwards Plateau to have 6 to 15 heads of leaves, and the leaf blade flat or concaved, with occasionally yellow margins.

14. *Yucca reverchoni*

(San Angelo yucca)

Yucca reverchoni Trel., Mo. Bot. Gard. Rpt. 22: 102. 1911.

Yucca rupicola Scheele, Linnaea 23: 143 (in part). 1850; Trel., Mo. Bot. Gard. Ann. Rpt. 13: 67 (in part). 1902.

Plant acaulescent, solitary but ultimately a dense small clump; clump 0.3 to 1.0 m. in diameter with 1 to 25 (6.7) heads of leaves; leaf head small, with

few leaves; leaf blade 25 to 55 (38) cm. long, 10 to 20 (14) mm. wide, linear to somewhat broader toward the center, concavo-convex, quite rigid, straight, light glaucous green; leaf margin hyaline yellow or occasionaly red or brown, minutely denticulate; scape 46 to 110 (83.84) cm. long, slender, glabrous to heavily floccose; panicle 25 to 42 (33.6) cm. above foliage, 36 to 100 (58.7) cm. long, narrowly ovoid or narrowly pyramidal, with few branchlets and flowers; flowers pendent, campanulate to somewhat globose, expanding but little at anthesis, white or greenish white; perianth segments ovate, sharply acuminate; sepals 38 to 60 (50.3) mm. long, 15 to 21 (18) mm. wide; petals 38 to 59 (50.4) mm. long, 19 to 29 (24.6) mm. wide; filaments 18 to 32 (25.7) mm. long; pistil 29 to 45 (38.0) mm. long; ovary 4 to 6 (4.8) mm. in diameter, tapering into style or rarely abruptly terminating in style; style 9 to 20 (15) mm. long, attenuate, white or greenish; capsule 38 to 59 mm. long, 18 to 31 mm. in diameter, rarely constricted, ellipsoidal with long-attenuate or short-attenuate beak and obconical pedicel; beak of dry capsule flaring, with long reflexed valve points; seed 5 to 6 by 6 to 7 mm., flat, thin, dull black, without marginal wing. (Pl. 23.)

TYPE: Twin Mountain, San Angelo, Tex., *Julien Reverchon,* May 20, 1908; Mo. Bot. Gard. No. 148679.

RANGE: McCamey, Upton County, Tex., and extending northeast, east, and southeast through Reagan, Irion, Crockett, Val Verde, Sutton, and Kinney Counties to the vicinities of San Angelo, Tom Green County; Fort McKavett, Menard County; Roosevelt, Kimble County; Vance, Real County; and Uvalde, Uvalde County, Tex. It is usually found on rocky limestone ledges and gravelly plains of dense brush, at 1,200 to 2,950 feet elevation. The plants are thinly scattered. Probably the best plants of the species occur approximately 1.5 miles north of Eldorado, Tex. The species flowers between the first of May and mid-June. Although the inflorescence is very attractive, the dense clump is rather untidy in appearance.

McKelvey (*25, p. 76*) had difficulty in separating *Yucca reverchoni* from stemless or short-stemmed plants of *Y. thompsoniana* and concluded it was an intermediate race between *Y. rupicola* and *Y. thompsoniana.* Relative to the race, McKelvey stated, ". . . fruit does not synchronize with foliage; . . . inflorescences show frequent abnormalities, several flowers united into one, rhachis and branchlets fasciate . . . The foliage of some, indeed of most, is long and rather slender, suggesting *Y. rupicola* influence; however, in certain specimens . . . it is short as in *Y. Thompsoniana* but too broad for that species . . . In the field, where this race is found, plants were neither universally acaulescent . . . nor truly arborescent . . but varied from stemless to shrublike, the stems prostrate to more or less erect and 0.3-0.7 m. in length; noticeable also was a vigorous growth which produced a denser, more untidy crown than is characteristic of either species."

Apparent Hybrids of *Yucca reverchoni* and *Yucca rupicola*

Along the Nueces and Rio Frio, in southern Uvalde, and in southern Edwards and Real Counties, Tex., apparent hybrids and hybrid segregates between *Yucca reverchoni* and *Y. rupicola* are quite common. These plants resemble *Y. reverchoni* in their small, dense clump and their light glaucous green leaves; and *Y. rupicola* in their long (42 to 56 cm.) more or less flaccid leaves. They are approximately midway between the two species in leaf width

(1.9 to 2.4 cm.), obliqueness, and undulation. The leaf margins are hyaline yellow, light brown, or deep reddish brown. Between Junction and Roosevelt, the growth habit of the hybrid is more characteristic of *Y. rupicola,* whereas the leaves closely resemble *Y. reverchoni.* At Roosevelt and near McCamey, occasional hybrids occur between plants of species in the *Y. rupicola* and *Y. glauca* alliances. These plants mainly resemble *Y. rupicola,* except for small, greenish, globose flowers with a short style, or resemble *Y. glauca,* except for nonfiliferous leaves that are frequently somewhat denticulate and occasionally denticulately keeled on the under surface.

Possible hybrids between *Y. reverchoni* and *Y. thompsoniana* are discussed under *Y. thompsoniana* (p. 40).

15. *Yucca neomexicana*

(New Mexico yucca)

Yucca neomexicana Woot. & Standl., U. S. Natl. Herbarium Contrib. 16: 115. 1913.

Yucca harrimaniae McKelvey, Yuccas Southwest. U. S. 2: 139 (in part). 1947.

Y. coloma Andrews, Cat. Rockmont Nursery 1926: 22.

Plant acaulescent, forming an open clump of 5 to 15 heads of leaves, 35 to 60 cm. apart, or rarely somewhat caespitose; head of leaves small, symmetrical; leaf blade 15 to 46 (20.5) cm. long, 7 to 20 (13) mm. wide, linear to lanceolate, concavo-convex, thin, rigidly spreading, but easily flexible, deep green, rather glaucous, pungent; leaf margin white or at length moderately filiferous, the fiber fine, straight; scape 13 to 44 (23) cm. long, glabrous; inflorescence mainly a simple raceme or rarely with a few short branchlets; raceme 0 to 20 (5) cm. above foliage, 45 to 70 (51) cm. long, rather openly flowered; flowers broadly campanulate, expanding but little, pendent, white or somewhat greenish white, commonly tinged wth pink or purple; perianth segments broad, obtuse; sepals 44 to 63 (53) mm. long, 19 to 31 (25.5) mm. wide; petals 42 to 62 (51.5) mm. long, 24 to 33 (29.5) mm. wide; filaments 17 to 28 (22) mm. long, very hirsute; pistil 27 to 36 (30) mm. long; ovary 5 to 7 (6) mm. in diameter, white or rarely pale green, abruptly terminating in style or shouldered at apex, with staminal depressions wanting or very slightly, and deep carpel sutures; style 9 to 13 (10.5) mm. long, slightly to heavily swollen toward middle, pale green or rarely white; capsule 30 to 40 mm. long, 20 to 25 mm. in diameter, cylindrical with short attenuate beak, usually deeply constricted toward center and flaring open on drying; seed small, thin, very narrow marginal wing. (Pls. 24, 25, 29,*D,* and 29,*E.*)

TYPE: Volcanic hill about half a mile north of Des Moines, Union County, N. Mex., *P. C. Standley 6208,* June 11, 1911, U. S. Natl. Herbarium Nos. 285240 and 685238.

RANGE: Extreme northeastern corner of Union County, N. Mex., adjacent northwestern corner of Cimarron County, Okla., and adjoining corners of Las Animas and Baca Counties, Colo. Similar plants, not completely identified but very likely the same species, occur in Mesa, Montrose, San Miguel, Ouray, and Gunnison Counties, Colo. *Yucca neomexicana* occurs mainly in open woodland at 3,900 to 8,000 feet elevation. It is thinly scattered and rarely spreads into the lower grasslands or chaparral. In woodland areas it is usually found

on exposed rocky ledges, where its rhizomes wind in and out of the narrow, soil-filled fissures of the ledges. Aimlessly dispersed along the rhizomes are solitary rosettes, forming a very open irregularly shaped clump. When the plants are found in the adjacent grasslands, the rhizomes are somewhat shorter and the rosettes more uniformly distributed. The clumps of such plants are quite dense and rather uniform in shape. The species usually flowers between the middle of May and the last of June.

In its New Mexico-Oklahoma range *Y. neomexicana* is quite uniform, and its leaves, inflorescence, height of flowering, and other plant characters deviate very little from the averages given in the species description. On the other hand, apparently because of extreme differences in elevation, the plants in western Colorado are quite variable. They are somewhat more clumped than the plants in New Mexico and Oklahoma, and the leaves are longer, more spatulate, and vary from deeply to rather shallowly concave. Near Sapinero, Gunnison County, Colo., at approximately 7,600 feet elevation, the plants have comparatively few leaves, which are 6 to 10 (7.3) mm. wide, 14 to 34 (23.7) cm. long, and deeply concaved. In the vicinity of Cimarron, Montrose County, at 5,900 feet elevation, the rosettes are larger, with numerous leaves, which are 12 to 15 (13.7) mm. wide, 43 to 46 (44.7) cm. long, and are rather shallowly concave.

Plants identified as *Y. harrimaniae* Trel., which the writer believes to be *Y. neomexicana,* were reported by McKelvey (*25*) in the vicinity of La Vita, Huerfano County, Colo., and by Standley[17] in Apache County, Ariz.

The writer confirms McKelvey's (*25*) findings that *Y. neomexicana* does not occur at the type locality. Although *Y. glauca* is fairly abundant in the vicinity, the nearest plants of *Y. neomexicana* were found to be some 35 miles east in the New Mexico-Oklahoma range of the species.

Although *Y. neomexicana* is frequently admixed with *Y. glauca* and *Y. baccata,* and occasionally with *Y. baileyi,* no evidence of hybridization with these species has been observed.

16. *Yucca gilbertiana*

(Salt Lake Desert yucca)

Yucca gilbertiana (Trel.) Rydb., Flora Rocky Mountains and Adjacent Plains, pp. 170, 1061. 1917.

Yucca harrimaniae var. *gilbertiana* Trel., Mo. Bot. Gard. Ann. Rpt. 18: 225. 1907.

Y. harrimaniae Trel., Mo. Bot. Gard. Ann. Rpt. 13: 59 (in part). 1902; McKelvey, Yuccas Southwest. U. S. 2: 139 (in part). 1947.

Plant acaulescent, forming a dense, small clump of 3 to 22 (6.5) heads of leaves, covering an area of 0.25 to 1.5 (0.8) m. in diameter; head of leaves asymmetrical or rarely small and symmetrical; leaf blade 12 to 50 (28.4) cm. long, 18 to 43 (30) mm. wide, lanceolate to spatulate-lanceolate, concavo-convex, deeply striate, rather thick and rigid, pale green, pungent; leaf margin white or brown, at length filiferous; fiber coarse and curly; scape 10 to 14 (11.4) cm. long, inflorescence mainly a simple raceme or rarely with few short branchlets; raceme extending 10 to 20 (16.8) cm. within foliage, 35 to 70

[17] *P. C. Standley 7314,* July 28, 1911, Deep Canyon, Navajo Indian Reservation, north end Carrizo Mountains, Apache County, Ariz., U. S. Natl. Herbarium No. 686280.

(44.4) cm. long, densely flowered; bract large and persistent; flowers broadly campanulate, expanding but little at anthesis, pendent, yellow or greenish yellow, commonly tinged with purple; perianth segments broad; sepals 41 to 60 (46.9) mm. long, 16 to 26 (19.9) mm. wide; petals 40 to 58 (47.3) mm. long, 21 to 34 (27.4) mm. wide; filaments 16 to 22 (18.6) mm. long; pistil 30 to 38 (32.9) mm. long; ovary 4 to 8 (5.9) mm. in diameter, pale green with pronounced carpel sutures and faint staminal depressions; style 9 to 11 (9.8) mm. long, swollen to diameter of 3 to 6 (4.4) mm. toward center, very pale green or white; capsule 35 to 45 mm. long, 22 to 30 mm. in diameter, cylindrical with short attenuate beak, usually deeply constricted toward center and flaring open when dried; seed 5 to 6 by 6 to 8 mm., thin, dull black, very narrow marginal wing. (Pls. 26, 27, and 29,*A*.)

TYPE: North end Fish Springs or House Range, western Utah, *G. K. Gilbert,* August 1901, U. S. Natl. Herbarium No. 392927.

RANGE: Burbank and Garrison, southwestern Millard County, north to Fish Springs, Juab County, Utah. The writer has studied the species in the southern end of the House Range, Millard County, Utah, at 4,700 to 6,200 feet elevation. In this section, it is thinly scattered in the low chaparral, on gravelly bajadas, and mountain slopes. Although the foliage of the species is rather attractive, its greenish-yellow flowers detract considerably from its decorative value. The species usually flowers around the middle of June.

Trelease's photograph (*32, pl. 12*) shows a potted plant of *Yucca gilbertiana* that is similar to many of these plants in their native habitat and clearly depicts the characteristic rough and ragged appearance. From a short distance such plants have the vegetative appearance of *Y. baccata. Y. gilbertiana* has a raceme similar to that of *Y. glauca.*

The writer has seen only one striking variant of *Y. gilbertiana.* This plant, occurring in the House Range, was well isolated from other species, and no plant in the vicinity exhibited evidence of intergrading into another species. The clump of the variant was very open, with scattered rosettes that were undoubtedly of rhizomatous origin. The rosettes were comparatively few-leaved and the leaves extremely short. Although the racemes were borne above the foliage, this characteristic was undoubtedly caused by the short leaves, as the scape and inflorescence were of normal length.

Comparison of *Yucca gilbertiana, Yucca neomexicana,* and *Yucca harrimaniae*

In the range indicated above, *Yucca gilbertiana* was not found to be associated with any other yucca. Transitional forms between *Y. gilbertiana* and *Y. neomexicana* are commonly admixed with *Y. baccata, Y. angustissima,* and *Y. elata.* No evidence of hybridization between any of the latter species and transitional forms of *Y. gilbertiana-neomexicana* has been observed.

Yucca gilbertiana, Y. neomexicana, and *Y. harrimaniae* Trel. *(31)*[18] compose a confusing alliance, which has frequently been considered a single species, *Y. harrimaniae.* Field, nursery, and laboratory studies, however, indicate that *Y. gilbertiana* and *Y. neomexicana* are easily separated by specific characters, while *Y. harrimaniae* appears to be an intermediate, variable race. The clumps of *Y. gilbertiana* are dense and small, whereas those of *Y. neo-*

[18] Type: Helper, Carbon County, Utah, *Trelease,* Aug. 4, 1899, and Sept. 7, 1901; Mo. Bot. Gard. Nos. 148566 to 148572.

mexicana are open and large; the heads of leaves of *Y. gilbertiana* are mainly of aerial origin, but those of *Y. neomexicana* are usually of rhizomatous origin; the leaf blades of *Y. gilbertiana* are 18 to 43 mm. wide, lanceolate to spatulate-lanceolate, somewhat wavy, very glaucous, and rather light green (pl. 29,*A*), but those of *Y. neomexicana* are 7 to 20 mm. wide, linear to narrowly lanceolate, straight, lightly glaucous, and dark green (pl. 29,*D*, and 29,*E*); the marginal leaf fibers of *Y. gilbertiana* are coarse and curly, whereas those of *Y. neomexicana* are thin and straight; the racemes of *Y. gilbertiana* are densely flowered (average, 38 flowers) and extend from 10 to 20 cm. into the foliage, whereas the racemes of *Y. neomexicana* are thinly flowered (average, 27 flowers), mainly well above the foliage and never extend into the foliage; and the basic flower color of *Y. gilbertiana* is greenish yellow and that of *Y. neomexicana* is white. The filaments of *Y. neomexicana* are considerably more hirsute than those of *Y. gilbertiana.*

Relative to *Y. harrimaniae,* Trelease *(31, p. 59)* described it as ". . . flowering from close to the base," whereas he (*32*) does not give the flowering habit of *Y. gilbertiana.* He reported the flowers of *Y. harrimaniae* as greenish, and the leaves as usually 6 to 15 or even 40 mm. wide; he does not note the flower color of *Y. gilbertiana,* but he reported the leaves of the latter as 20 mm. wide. With regard to *Y. gilbertiana,* Trelease *(32, p. 225)* stated it to be " a rather striking form in its very rough papillate leaves, those of the type [*harrimaniae*] being entirely smooth or with a few mostly low papillae near the apex."

Rydberg *(28, p. 170)* raised the status of *Y. gilbertiana* from a variety of *Y. harrimaniae* to that of a distinct species, and described its leaves as "linear, about 4.5 dm. long, 2 cm. wide, openly concave . . ." He stated that *harrimaniae* leaves are "linear to lanceolate, 6-40 mm. wide . . ."

McKelvey (*25, p. 145*) merged *Y. gilbertiana* and *Y. neomexicana* under *Y. harrimaniae* and reported, " . . . to a varying degree papillae are present on leaves of this species throughout its range." McKelvey also stated, "The flowers of this type [*gilbertiana*] must be considered similar to those of *Y. Harrimaniae* until proof is forthcoming that at anthesis the style is white rather than the apple-green color of the typical form."

The writer found that the leaves of *Y. gilbertiana* were coarser and rougher than those of *Y. neomexicana,* but that the character depends upon the coarseness of striation, rather than papillae, which were present in varying degrees in both species, as McKelvey observed. The ovaries of *Y. gilbertiana* were pale green and the styles were slightly lighter green or occasionally white, whereas in *Y. neomexicana* both ovaries and styles were pale green or white.

According to McKelvey (*25*) D. M. Andrews, Rockmont Nursery, Boulder, Colo., is of the opinion that *Y. harrimaniae* and *Y. neomexicana* are distinct species. In support of this contention, Mr. Andrews pointed out that the range of *Y. neomexicana* (New Mexico, Oklahoma, southeastern Colorado) is widely separated from that of *Y. harrimaniae* (west-central Colorado, Utah) and that the leaves of *Y. harrimaniae* are more spatulate than those of *Y. neomexicana.* Although there is no question that the leaves of the majority of plants in Utah and western Colorado are more spatulate than those of the eastern plants, many leaves from plants in the former sections are indistinguishable in shape and size from those of the latter range. McKelvey cited specimens of this group of plants in Costilla and Huerfano Counties, Colo., that were approximately midway between the eastern and western ranges of the plants.

Relative to *Y. harrimaniae* and the type locality, (Helper, Utah), McKelvey *(25)* reported that the plants begin 3 or 4 miles north of the town and that the largest ones produced procumbent stems, not more than a meter long. McKelvey further stated that in these plants flowering started well down in the foliage and that the styles were nearly oblong-cylindrical, very slender, and apple green (darker than the ovary at anthesis). In August 1948, the writer found abundant plants within the city limits, slightly north of the railroad yards. These plants were very similar to *Y. neomexicana* in rosette distribution (open clump), in leaf size and shape, in flowering stalk height, and in capsule size and shape. They differed only in that the leaves were slightly more filiferous and the fibers were somewhat curled. None of the plants had aerial stems, and the height of flowering could not be determined. Previous examinations of plants from the vicinity of Price, a nearby locality, showed that the racemes extended well into the foliage and that the styles were frequently quite tumid and varied in color from pale green to nearly white. It is the writer's opinion that the yuccas of *Y. harrimaniae* alliance in the environs of Helper and in other parts of Utah are hybrids or recombinations between *Y. neomexicana* and *Y. gilbertiana,* and that McKelvey's observations partly involved such plants.

Apparent Hybrids of *Yucca gilbertiana* and *Yucca neomexicana*

Apparent hybrids of *Yucca neomexicana* and *Y. gilbertiana* extend from the Duchesne and Uintah Counties, Utah, southwest to Iron, Piute, and to southwestern San Juan Counties, Utah. In the north and southeastern part of this range the plants closely approach *Y. neomexicana,* but in the central and southwest they are quite similar to *Y. gilbertiana.* The majority of plants resemble *Y. gilbertiana* in their small caespitose clump and long, broad leaves with coarse, curly fibers, and approach *Y. neomexicana* in their thinly flowered raceme and basically white flowers. Although the racemes usually extend slightly into the foliage, they rarely appear as low in *Y. gilbertiana* and not uncommonly it begins at foliage level or even several centimeters above the foliage. (Pls. 28, 29,*B,* and 29,*C*). Plants resembling *Y. gilbertiana* in all characters except height of flowering and flower color are particularly common from Manderfield south to Paragonah, Utah, whereas those differing from *Y. neomexicana* only in their dense caespitose clump, low flowering habit, and curly leaf marginal fibers are common in the vicinities of Price and Helper, and in San Juan County, Utah.[19] Rarely between Price and Helper are the clumps open as in *Y. neomexicana.*

17. *Yucca glauca*

(Great Plains yucca; locally, beargrass, soapweed)

Yucca glauca Nutt., Fraser's Catalogue of New and Interesting Plants, No. 89. 1813; reprinted in Pittonia 2: 115. 1890.

Yucca angustifolia Pursh, Flora Amer. Sept., p. 227. 1814.
Y. glauca Trel., Mo. Bot. Gard. Ann. Rpt. 13: 59 (in part). 1902.

Plant acaulescent or with short stems (0.3 m.), solitary but soon clumped;

[19] Goosenecks, San Juan County, Utah, *W. P. Cottam,* April 30, 1935, Univ. Utah Herbarium, No. 5812.

clump small (0.8 to 2.5 m. in diameter), dense (6 to 15 or more heads of leaves per square meter); head of leaves rather small; leaf blade 50 to 70 (56.6) cm. long, 0.5 to 1.1 (0.9) cm. wide, linear, plano-convex, occasionally triquetrous or nearly flat, striate, divergently spreading, flexible, pale green or pallid; leaf margin white or greenish white, soon finely filiferous; flowering stalk 88 to 125 (107.6) cm. long; scape 24 to 53 (36.0) cm. long; inflorescence extending 5 to 21 (12.8) cm. into foliage, usually simple or rarely with few, abortive branchlets at base; flowers globose or campanulate, greenish white, commonly tinged with purple and shiny; perianth segments thick, brittle, broad, and acute; sepals 45 to 56 (50.8) mm. long, 26 to 33 (28.5) mm. wide; petals 48 to 61 (53.9) mm. long, 31 to 42 (36.8) mm. wide; filaments 20 to 30 (21.1) mm. long; pistil 29 to 37 (33.1) mm. long; ovary 9 to 13 (10.8) mm. in diameter, obovoid, white or rarely greenish white, carpel sutures faint, anther depressions prominent, abruptly terminating in style; style 8 to 13 (10.2) mm. long, very tumid or swollen to 6 to 10 (7.3) mm. in diameter toward center, dark green or rarely medium green; capsule 58 to 62 (60.1) mm. long, 45 to 53 (48.5) mm. in diameter, oblong-cylindrical, mucronate, with occasionally 1 or 2 valves slightly constricted; seed 7 to 9 by 8 to 10 mm., thin, smooth, dull black, broad marginal wing. (Pls. 30, 34,*A*, 35,*A*, and 36,*A*.).

TYPE: 1,600 miles up Missouri River, about lat. 49, type specimen not located. McKelvey *(25)*: ". . . most probably in the general region of Fort Mandan, North Dakota."

RANGE: From Cottle and Floyd Counties, Tex., northwest through the Oklahoma Panhandle and extreme northeastern New Mexico, into the southeast quarter of Colorado. The species is also reported to occur in Kansas, Nebraska, northwestern Missouri, central South Dakota, and southern Wyoming. The writer has collected typical plants of the species on the eastern slopes of the Big Horn Mountains, north-central Wyoming, and in the eastern part of the Badlands National Monument, S. Dak. In the greater part of its range, *Yucca glauca* is rather thinly scattered on the rolling, well-drained grassland plains, at 1,600 to 2,800 feet elevation. In many areas, however, particularly in Colorado, it occurs in open woodlands at 2,000 to 6,500 feet elevation. Around Calhan, Simla, and Kiowa of El Paso and Elbert Counties, Colo., comparatively large, dense concentrations of *Y. glauca* are rather common. Similar concentrations are reported in Logan, Phillips, and Sedgwick Counties. The species usually flowers between May 15 and June 30.

On three occasions in the field and one in the nursery, the writer observed cases of phyllody in *Y. glauca*. In all instances the young inflorescence then was highly foliaceous. The inflorescence leaves were slightly shorter and broader than normal, and their apices are particularly pungent and curved abruptly inward, forming apical hooks.

A striking variant patch of *Y. glauca* occurs near Kiowa, Colo. This variation is described under Ecology and is probably caused by soil conditions. It mainly involves a change in plant habit and leaf character.

Under *Y. baileyi* are described nanate plants that occur in Colorado at 8,800 to 9,000 feet elevation. These may prove to be *Y. glauca*.

Two forms of *Y. glauca* have been described. Variety *stricta* (Sims) Trelease *(31)*, later renamed variety *garneyi* McKelvey *(25)*, is mainly distinguished by its robust growth and its conspicuous panicle with a long racemose tip. It is reported to occur in Oklahoma, Kansas, New Mexico, and Colorado. Such plants (pl. 31) are rather uncommon, and the writer is of the

opinion that they are results of hybridization or of particularly good growing conditions. They are usually found along roadsides or in areas where other vegetation is likewise exceptionally good.

Throughout the greater part of northern New Mexico and extreme western Texas and to some extent into the Oklahoma Panhandle the plants usually identified as *Y. glauca* are extremely variable and lack constant characters. In general, the yuccas in these regions appear to be gradients of *Y. glauca* and closely allied species (see pls. 31-43). They are treated under transitional forms (p. 56).

18. *Yucca baileyi*

(Alpine yucca)

Leaves linear, mainly long (29 to 56 cm.), narrow in proportion to length..... Y. BAILEYI.

Leaves linear to oblanceolate, short (11 to 41), broad in proportion to length.... Y. BAILEYI var. NAVAJOA.

Yucca baileyi Woot. & Standl., U. S. Natl. Herbarium Contrib. 16: 114. 1913.

Yucca standleyi McKelvey, Yuccas Southwest. U. S. 2: 108. 1947.

Plant acaulescent or rarely with short ascending stems, solitary but soon clumped; clump small (0.6 to 2.0 m. in diameter), dense (usually 3 to 18 heads of leaves); leaf blade 20 to 56 (46.3) cm. long, 0.3 to 0.8 (0.6) cm. wide, linear, plano-convex, occasionally triquetrous or nearly flat, striate, divergently spreading, flexible, often falcate, pale green or yellow green; leaf margin white, soon finely filiferous; flowering stalk 35 to 120 (63) cm. long; scape 7 to 21 (14.3) cm. long; inflorescence a simple raceme extending 5 to 20 (13.0) cm. into foliage, densely flowered; flowers campanulate or decidedly globose, greenish white, usually deeply tinged with purple, shiny; perianth segments rather thin, ovate or obovate; sepals 40 to 53 (46) mm. long, 18 to 22 (20.1) mm. wide; petals 40 to 53 (44.1) mm. long, 26 to 31 (28.7) mm. wide; filaments 21 mm. long; pistil 27 to 29 (27.8) mm. long; ovary 7 to 9 (8.1) mm. in diameter, stout, oblong or obovoid, very pale to fairly dark greenish white, carpel sutures well marked, anther depressions usually faint or rarely well marked, abruptly terminating (shouldered) in style; style 7 to 9 (8.3) mm. long, slender, white or pale greenish white; capsule 44 to 70 (59) mm. long, 27 to 51 (38.5) mm. in diameter, oblong with oblate apex and mucronate tip, seldom constricted; seed 8 to 10 by 9 to 12 mm., thin, smooth, black with broad marginal wings. (Pls. 34,*B*, 35,*B*, 36,*B*, and 44.)

TYPE: Dry slope in pine woods in the Tunitcha Mountains, San Juan County, N. Mex., *P. C. Standley 7638*, August 8, 1911, U. S. Natl. Herbarium No. 686602.

RANGE: Coconino, Navajo, and Apache Counties, Ariz., east and northeast into McKinley, San Juan, and Valencia Counties, N. Mex., and La Plata, Archuleta, and San Juan Counties, Colo. It is also reported to occur in San Juan County, Utah, and to extend as far north, northeast, and east, respectively, as Mesa, Larimer, and Las Animas Counties, Colo. The species is thinly scattered in grasslands and woodlands at 4,000 to 8,000 or more feet elevation. It usually flowers from mid-May to mid-June.

Although on several occasions, mainly in June 1945 and early August 1948, the writer has studied the yuccas from Canon City, Fremont County, to

Monarch Pass, Chaffee County, Colo., he has not found them in flower and has been unable to determine their identity. *Yucca baileyi* has been reported near Canon City (about 5,500 feet elevation), and the leaves, old flowering stalks, and capsules of the plants in the section appear to resemble those of that species. From Canon City west, however, the yuccas become increasingly small, until approximately 8 miles east of Monarch Pass they are quite different from *Y. baileyi.* In the latter vicinity, the yuccas occur in small, dense patches on rocky slopes at 8,800 to 9,000 feet elevation. The plants form few rosettes, and the clumps are very open. The rosettes contain very few leaves; the leaf blades are short (25 to 33 (28.3) cm.) and very narrow (4 to 6 (5) mm.) but deeply concave; the flowering stalks are short (30 to 60 (40) cm.); and the capsules are small and commonly deeply constricted. In many respects the plants resemble *Y. neomexicana,* and, irrespective of high elevation and the gradual approach of the nanate condition, they may represent a transitional form of *Y. baileyi* (or *Y. glauca*) and *Y. neomexicana.*

Upon examination of the type specimen of *Y. baileyi* (U. S. Natl. Herbarium No. 686602), McKelvey *(25)* noted that the upper bracts were foliaceous and that the pistil was exceptionally large (5 cm. long) and similar in form to those found in the *Baccatae.* She further found that in the type locality (Tunitcha Mountains, N. Mex.) the plants rarely formed foliaceous bracts and none of the flowers had pistils similar in size and form to that of the type specimen. These conditions and the fact that *Y. baccata* was common in the type locality of *Y. baileyi* led McKelvey to the conclusion that the type collection represented a hybrid between *Y. baccata* and the capsular-fruited species of the area. She, therefore, concluded that the name *Y. baileyi* was inapplicable to the common capsular plant of the vicinity and named it *Y. standleyi.* McKelvey, however, noted that the original description of the type specimen of *Y. baileyi* was similar to that of *Y. standleyi* in plant and inflorescence habit and in leaf and fruit form and size.

It is the writer's opinion that the *Y. baileyi* type differs from *Y. standleyi* only in its foliaceous bracts. Although he also finds the pistil of the *Y. baileyi* type specimen exceptionally large, he finds that its oblong ovary with very oblate apex and slender style is indistinguishable from that of other capsular yuccas of the type locality, rather than similar to or suggestive of *Y. baccata's* fusiform ovary and style. It is very likely that the exceptionally large-sized pistil of the type specimen is caused by its age. In all yuccas, the perianth segments remain fresh several days following anthesis. During this period, presumably owing to fecundation, the ovary and, to some extent, the style develop very rapidly. Yucca flower measurements are usually made at anthesis at the height of the flowering season.

McKelvey's type specimen of *Y. standleyi* (No. 4609), Tunitcha Mountains, was collected May 24, 1934. Standley's type specimen of *Y. baileyi* was collected August 8, 1911. At such a late date, it is very likely that Standley had very little choice of flower material and was forced to take an old flower, whether or not the plant had foliaceous bracts. Except for the latter variation, which occasionally occurs in other yuccas, the *Y. baileyi* type specimen is similar to all other capsular-fruited plants in the type locality. It therefore appears unwarranted to rename the group in favor of the majority of plants, and exclude those exhibiting the minor variation.

Yucca baileyi and *Y. glauca* are similar, and it would undoubtedly be difficult to distinguish hybrids between them or to determine which one of them

was involved in hybrids with other species. In vicinities where *Y. baileyi* and *Y. angustissima* are relatively close together, however, the clumps of *Y. baileyi* are rather large and open, suggesting the influence of *Y. angustissima*. Such possible hybrids are discussed on page 56.

Yucca baileyi variety *navajoa*

Yucca baileyi var. *navajoa*. (Webber) comb. nov.

Yucca navajoa Webber, Madroño 8: 105. 1945.

Variety *navajoa* differs from typical *Yucca baileyi* in the following respects: (1) It is usually subcaulescent rather than acaulescent; (2) its dense clump is mainly caused by the branching of aerial stems (0.4 to 1.2 m. tall) rather than to branching of subterranean stems; (3) its heads of leaves are smaller and more symmetrical than those of the species; and (4) its leaves are broader (average, 8 mm.) in comparison to their length (average, 23 cm.) (frequently oblanceolate) than those of the species. The seeds of a single plant at the type locality were small (average, 6 by 7 mm.) and lacked the broad marginal wing characteristics of the species. (Pl. 45.)

TYPE: Five miles north of Tohatchi, McKinley County, N. Mex., *Webber*, 1944; U. S. Natl. Herbarium No. 1872608.

RANGE: Three miles north of Tohatchi, McKinley County, N. Mex., extending north for approximately 6 miles and west into the Chuska Mountains, possibly as far as the Little Colorado Gorge, Coconino County, Ariz. The variety is usually scattered in chaparral and juniper woodlands on coarse gravelly soil or sandstone ledges, at 5,200 to 6,500 feet elevation. It usually flowers in early June.

Although the leaves of variety *navajoa* are small, they are quite different from the small leaves of the dwarf forms of *Y. baileyi*, which occur in the vicinity of Keams Canyon and south of Holbrook, Ariz. The leaves of the dwarf plants are narrow and frequently needlelike, whereas those of variety *navajoa* are broad and commonly oblanceolate. Furthermore, variety *navajoa* always appears vigorous, having as large an inflorescence as and forming more rosettes than *Y. baileyi;* the nanate forms of *Y. baileyi* appear stunted, having short inflorescences and few rosettes.

In the vicinity of the Little Colorado Gorge, northwest of Cameron, Coconino County, Ariz., the yuccas resemble variety *navajoa*, but in many characters they appear midway between variety *navajoa* and *Y. baileyi*. These plants frequently have aerial stems 0.30 to 0.45 m. tall that are moderately branched. The leaves are short, narrow to broad, and linear to oblanceolate. These plants, however, do not have so many stems or rosettes as variety *navajoa*, and they do not form large, dense clumps. It appears very likely that these yuccas are border plants of the variety *navajoa* and that the range of the variety extends from the vicinity of Tohatchi, N. Mex., west through the Chuska Mountains to the Little Colorado Gorge. Kearney and Peebles *(20)* referred to the Little Colorado Gorge plants as an unnamed variety of *Y. baileyi* and described them as having exceptionally short and rather coarsely filiferous leaves.[20] McKelvey *(25)* believed they were juvenile forms of the species *(Y. standleyi)*.

[20] Such coarse-fibered plants as Kearney and Peebles No. 12819, Sacaton Herbarium, U. S. Cotton Field Station, Sacaton, Ariz., are quite rare in the locality. The leaves of the specimen are narrowly oblanceolate.

The writer has found one striking variant in variety *navajoa* that differs from the normal in the same manner as the variant form of *Y. gilbertiana* described on page 45. This variant occurred in the center of a rather dense concentration of *navajoa,* approximately 5 miles north of Tohatchi, N. Mex. The plant had scattered rosettes of rhizomatous origin and lacked aerial stems. Its rosettes were small, and its leaves were extremely short and broad for their length. The scape and raceme were normal length and the raceme, probably owing to the short leaves, were borne at foliage level.

19. *Yucca angustissima*

Yucca angustissima Engelm. ex Trel., Mo. Bot. Gard. Ann. Rpt. 13: 58. 1902.

Plant acaulescent or rarely with short (0.1 to 0.5 m.), procumbent stems; solitary but at length clumped; clump large, open with 20 or more heads of leaves at a density of 1.8 to 5.3 per square meter; head of leaves symmetrical; leaf blade 28 to 57 (44.8) cm. long, 0.4 to 0.8 (0.6) cm. wide, striate, plano-convex, rarely triquetrous or nearly flat, linear, rigidly divergent, flexible, pale blue green; leaf margin white or greenish white, eventually filiferous, the fibers fine, loosely curled; flowering stalk 90 to 122 (105) cm. long; scape 28 to 34 (31.2) cm. long, slender; inflorescence simple or rarely with 2 or 3 short abortive branchlets toward base, 15 to 26 (20.3) cm. above foliage; flowers campanulate to globose, greenish white, the outside tinged with purple and glossy; perianth segments elliptical, brittle; sepals 31 to 40 (37) mm. long, 19 to 23 (22) mm. wide; petals 31 to 39 (35.1) mm. long, 28 to 32 (30.5) mm. wide; filaments 22 to 24 (23.1) mm. long; pistil 25 to 28 (27) mm. long; ovary 7.0 mm. in diameter, slender, ovoid, more or less tapering into style, pale green or nearly white; staminal depressions and carpel sutures moderately deep; style 4 to 6 (5) mm. long, slender or somewhat ovoid at union with ovary, nearly white or pale green; capsule 38 to 42 (41.3) mm. long, 30 to 33 (31) mm. in diameter, commonly with deep central constriction, dehiscent for entire length but twisted and flaring open above constriction; seed 5 to 7 by 7 to 8 mm., thin, dull black, with fairly narrow marginal wing. (Pls. 46, 34,*C*, and 35,*C*.)

TYPE: Deserts of the Colorado River area, *J. M. Biglow,* 1854, Mo. Bot. Gard. No. 148375; McKelvey *(25)* near Picacho, Ariz.

RANGE: Coconino, Mohave, and Yavapai Counties, Ariz., and in Washington and Grand Counties, Utah. It is also reported to occur in Apache County, Ariz., and in Rio Arriba and Valencia Counties, N. Mex. The writer has collected specimens closely resembling the species in Navajo County, Ariz., and in southeastern Nevada. The plants in the latter areas, however, as well as those in New Mexico, Utah, and Apache County, Ariz., are quite variable, and the majority of them exhibit characters of *Yucca glauca* (or *Y. baileyi*) and *Y. elata.* The species is thinly scattered in grass, woodlands, and chaparral at 2,500 to 7,500 feet elevation. It usually flowers in May or early June.

With reference to the habit of *Y. angustissima,* McKelvey *(25, p. 106)* stated "Individual plants as a rule produce a single head of leaves or but few heads in one clump." Although plants with a single head of leaves occur, those with many heads, widely scattered but connected by subterranean stems, are far more abundant. In the majority of yuccas, the area of the

clump (or a single plant) is easily determined by tracing minor variations of the individual.

In areas where *Y. angustissima* is removed from other capsular forms of yucca, it exhibits very little variation. Possibly the greatest variations in the species are in the color of its style, the amount of capsular constriction, and the branching of the inflorescence. The styles vary from pure white to fairly dark green, and they are occasionally rather yellowish. All plants have constricted capsules, but the degree of constriction varies from shallow to very deep, and the number of capsules constricted varies from approximately 60 to 100 percent. In several localities, mainly around Peach Springs, Seligman, and Paulden, Ariz., the inflorescences are unbranched, and elsewhere scattered plants with inflorescences having a few short branchlets at or near the base occasionally occur.

From Whiteriver north to McNary and Show Low, Ariz., the yuccas are very confusing. The majority of plants in this area occur between 6,000 and 6,500 feet elevation in open woodlands of deep, coarse sand, which is often packed solid, like hardpan. The yuccas are either typical *Y. angustissima* or plants that exhibit characters of both *Y. angustissima* and *Y. elata*. Both types of plants have small heads of leaves, and the leaves are short and narrow. Plants of *Y. angustissima* have typical flowers and capsules, but their racemes may be either normal size or extremely short. Except for their slender ovoid ovaries that taper into the styles and for their small constricted capsules, both types are quite similar to the dwarf plants of *Y. baileyi* occurring a few miles north, between Snowflake and Holbrook.

Yucca angustissima is similar to *Y. glauca* and *Y. baileyi,* and it is the writer's opinion that much of the difficulty in separating the species is owing to hybridization between members of the three species (see pl. 36,*D, E,* and *F*). Apparent hybrids and transitional forms are described on page 56. *Y. angustissima* is occasionally admixed with or in close proximity to *Y. elata,* and these two species also intergrade (see pl. 37,*E,* and *F*) p. 62).

20. *Yucca constricta*

Yucca constricta Buckl., Phila. Acad. Nat. Sci. Proc., 1862: 8. 1863.

Yucca constricta Trel., Mo. Bot. Gard. Ann. Rept. 13: 54-56 (in part). 1902.

Plant acaulescent or with short procumbent stems 0.2 to 0.4 m. long; clump small to large, open with 1 to 20 heads of leaves 0.2 to 0.9 m. apart; head of leaves large, asymmetrical or rarely small and symmetrical; leaf blade 29 to 65 (44.1) cm. long, 0.8 to 1.5 (1.1) cm. wide, linear or somewhat broader toward center, nearly flat or plano-convex, occasionally triquetrous, striate, rigidly divergent, flexible, pale to dark green; leaf margin white or green, eventually filiferous, the fiber fine, straight or curled, soon eroding away; flowering stalk 1.53 to 3.20 (2.07) m. long, slender and weak; scape 0.95 to 2.00 (1.31) m. long; inflorescence paniculate; panicle 0.20 to 0.46 m. above foliage, 0.45 to 1.20 (0.76) m. long, occasionally 0.7 m. in diameter at base, ovoid or broadly conoid, open-flowered, with few (8 to 15) branchlets; flowers small, hemispherical or cup-shaped, pale greenish white; perianth segments thin, acute, ellipsoidal, sepals 35 to 45 (41.5) mm. long, 11 to 21 (16.1) mm. wide; petals 37 to 48 (42.4) mm. long, 17 to 26 (22.0) mm. wide; filaments

17 to 22 (19.1) mm. long; pistil 25 to 38 (27.1) mm. long; ovary 5 to 6 (5.5) mm. in diameter, slender, cylindrical with oblate apices, pale green, carpel sutures prominent, anther depressions faint or wanting, abruptly terminating (shouldered) in style; style 8 to 11 (9.1) mm. long, cylindrical with basal lobes extending slightly over ovary, whitish green or pale green (darker than ovary); capsule 46 to 63 (53) mm. long, 36 to 43 (39.5) mm. in diameter, oblong-cylindrical, mucronate, 17 to 92 percent constricted; seed 7 to 9 by 9 to 15 mm., thin, glossy black, with broad marginal wing. (Pls. 34,*D*, 35,*D*, and 36,*C*, and 47.)

TYPE: Western Texas, *S. B. Buckley*, 1861-62, Elias Durand Herbarium. (McKelvey *(25)* thought it was from the eastern end of Edwards Plateau.)

RANGE: Gillespie County south to southern Dimmit County and southwest to the vicinity of Del Rio, Val Verde County, Tex. The species is also reported to extend from the latter section as far east as Galveston County; as far west as the Pecos River basin; and as far north as the Oklahoma-Texas State line. In the two latter sections, however, the species is extremely variable and blends into *Yucca glauca* and *Y. elata*. The species is thinly scattered in brushwood and grasslands at 900 to 2,400 feet elevation. The plants usually flower in May.

McKelvey *(25, p. 130)* stated, "The leaves of the type sheet of *Y. constricta* are grass-like and, therefore, do not conform to those attributed to that species by Trelease which (in his description) are 'rather rigidly divergent,' (in his key) 'more rigid and spreading' than the 'grass-like' ones of his *Y. tenuistyla*. Trelease's concept (1902) of Buckley's species and the identification of Buckley's plant by Engelmann (1873), Baker (1880), Sargent (1896) and Trelease (1898) with the one now called *Y. elata*, certainly indicates that Buckley's type was not examined by any of these botanists; for the foliage of *Y. elata* is wiry and, where the blade is least thickened, flexible at most; it is never grass-like in the sense used by Trelease and the present writer; Buckley only refers to the length and breadth of the leaves, not to their texture."

The writer has indicated that he has been unable to separate many species by their leaf texture. Among these plants are such species as *Y. glauca, Y. baileyi, Y. angustissima, Y. elata,* and *Y. constricta*. The texture, as well as the habit, size, and shape of the leaves in these species, is extremely variable. In all of them the leaves can best be described as rigidly divergent, with common variations being more or less rigid and spreading, wiry or grasslike. In general the leaves of nanate forms are very rigid, firm, and divergent, whereas those of normal-sized plants are divergent but flexible. The leaves of exceptionally longleaved plants are either rigid, flexible, and divergent or wiry, flexible, and drooping. Juvenile and, frequently, mature leaves, especially in heads where the leaves are twisted, appear grasslike. Aside from juvenile plants, the only truly flaccid or grasslike-leaved plants the writer has found in these species are variants of *Y. glauca* occurring near Kiowa, Colo. Undoubtedly the variation is caused by environmental conditions. It is discussed under the section entitled "Ecology."

McKelvey *(25)* also described the leaves of *Y. arkansana* Trel. as grasslike and those of *Y. harrimaniae, Y. neomexicana,* and *Y. gilbertiana* as somewhat intermediate between grasslike and wiry. *Y. arkansana* occurs somewhat east of the range covered by the present monograph, and the writer has not studied the species. Many plants of *Y. neomexicana*, especially those with fine fibers

that occur in New Mexico, Oklahoma, and eastern Colorado, are somewhat grasslike. The plants occurring in Utah, however, especially those with coarse fibers (*Y. gilbertiana*), are rather rigid or frequently very rigid.

The writer has not seen the type specimen of *Y. constricta.* If the leaves of the type are strictly grasslike, then he is convinced that few, very probably no, similar plants occur in the territory he has covered (west of Gillespie County, south to southern Dimmit County, Tex.). If in such species as *Y. elata, Y. glauca, Y. angustissima, Y. constricta,* and even *Y. neomexicana,* minor leaf characters (known to be variable) must conform to those of the type, then the majority of plants now identified as these species must be excluded. Buckley in his description of *Y. constricta* does not refer to leaf texture. Noting the similarity of *Y. tenuistyla* Trel. to *Y. constricta* and of *Y. louisianensis* Trel. to *Y. tenuistyla,* McKelvey *(25)* concluded that *Y. tenuistyla* and *Y. louisianensis* were possible synonyms of *Y. constricta. Y. tenuistyla* and *Y. louisianensis* occur east of the region surveyed by the writer, and, therefore, they have not been included in this study.

Yucca glauca Alliance

Species

In the writer's opinion, *Yucca angustissima, Y. baileyi, Y. glauca,* and *Y. constricta* form an alliance of closely related species that are quite similar in many characters and frequently intermingle with each other. *Y. elata* is closely related to the alliance and possibly should be included in it. It freely intermingles with all members of the alliance and is quite similar morphologically. McKelvey *(25)* divided the Chaenocarpa section into six series, based mainly upon leaf and style differentiation. *Y. angustissima* and *Y. baileyi* (*Y. standleyi* McKelvey) were placed in the Elatae series, distinguishd by wiry leaves and white to pale-green, rather slender styles and closely related to *Y. elata* and several new species. *Y. constricta* was placed in a series of its own, Constrictae, distinguished by slender, white or greenish styles and grasslike foliage and rather closely related to *Y. angustissima, Y. standleyi,* and *Y. harrimaniae. Y. glauca* was placed in Glaucae series, distinguished by stout, ovoid, apple-green styles and wiry leaves. These conclusions differ from those of the writer mainly in that *Y. angustissima* and *Y. baileyi* are more closely related to *Y. elata* than to *Y. constricta* and *Y. glauca* and that *Y. glauca* is quite distinct, being separated by *Y. harrimaniae* and several new intermediate species.

Typical plants of the *Y. glauca* alliance may easily be distinguished by the habit in connection with other characters. *Y. glauca* forms a small dense clump, has a racemose inflorescence extending well into the foliage, a broad-shouldered ovary, and very dark green tumid style. *Y. baileyi* forms an equally dense clump, with a raceme extending into the foliage, a broad-shouldered ovary, somewhat smaller leaves, shorter flowering stalk, and pale-green or white, comparatively slender style. *Y. angustissima* forms an open clump, has a racemose inflorescence borne above the foliage, slender ovary tapering into the style, pale-colored, rarely swollen style, and smaller, usually constricted capsules. *Y. constricta* forms an open clump, has a panicled inflorescence with exceptionally long peduncle, slender ovary, pale-colored, slender style, and smaller constricted capsules.

Apparent Hybrids

Yucca glauca Trel., Mo. Bot. Gard. Ann. Rpt. 13: 59 (in part). 1902.

Y. intermedia McKelvey, Yuccas Southwest. U. S. 2: 116. 1947.

Throughout the northern half of New Mexico and well into adjacent parts of Texas and Oklahoma and in the southwestern corner of Utah and adjacent Nevada, the majority of capsular-fruited yuccas lack constant characters and they are difficult to identify or classify as named species or forms. Although occasionally a plant or a group of plants approaches a named type, the majority of them appear to be hybrids or hybrid derivatives. Many of the apparent hybrids are midway between two named types, whereas others appear to be of quite remote hybrid ancestry, and still others to have involved several named types in their origin. The large area in New Mexico and adjacent Texas appears to be mainly a transitional zone between *Yucca glauca, Y. baileyi,* and *Y. angustissima,* and to a lesser degree between these members of the *Y. glauca* alliance and *Y. elata.* The area in southwestern Utah and adjacent Nevada appears to be a remote section of *Y. elata,* in which hybrids and recombinations of *Y. angustissima* and *Y. elata* are plentiful. The relatively large area between Lamesa and Abilene, Tex., and south to the vicinities of McCamey and Junction, Tex., appears to be a zone of hybrids between *Y. glauca* and *Y. constricta.* The fourth transitional zone appears to be between members of the *Y. glauca* alliance and *Y. elata.* This zone varies between 25 to 100 miles wide, along an imaginary line from Prescott, Ariz., to Roswell, N. Mex., and east into Texas.

On the United States Department of Agriculture Field Station grounds at Tucumcari, N. Mex., is a patch of native yuccas that clearly illustrates the perplexity of the majority of yuccas in the transitional zones. This patch covers approximately 30 to 35 acres of gentle sloping grassland, at about 4,100 feet elevation. Throughout the field, the soil appears to be fairly deep, sandy loam. The common and outstanding variations in this field are as follows: Leaf blade 25 to 64 cm. long, 0.2 to 1.3 cm. wide; flowering stalks 30 to 132 cm. long; scape 0 to 79 cm. long; panicle 30 to 85 cm. long; inflorescence 35 cm. within foliage to 38 cm. above; perianth segments 24 to 57 mm. long and 14 to 33 mm. wide; filaments 15 to 26 mm. long, pistil 20 to 34 mm. long; ovary 6 to 10 mm. in diameter; style 5 to 12 mm. long, 2 to 6 mm. in diameter; capsule 45 to 75 mm. long, 36 to 50 mm. in diameter, constricted or not constricted and widely dehiscent or completely indehiscent.

The majority of plants resemble *Y. glauca,* with moderately branched panicles, although occasionally plants resemble *Y. angustissima, Y. baileyi,* and *Y. constricta.* Each form exhibits many characters that intergrade into the other form, and only a few plants approach typical species. All of the plants resembling *Y. glauca* differ from typical *Y. glauca* at least in their larger, more or less open clump and their pale-green or white, moderately tumid or slender styles. Plants resembling *Y. angustissima* differ from typical *Y. angustissima* mainly in their larger, nonconstricted capsules, whereas a few differ in their greener and more tumid styles. Plants that resemble *Y. glauca* and *Y. baileyi* are frequently very similar and are mainly distinguishable by the slender, white style and broad, cylindrical capsules of *Y. baileyi.* Plants similar to *Y. constricta* have long peduncles and fairly broad panicles. In many respects these plants appear intermediate between *Y. glauca* and *Y. constricta.* (Pls. 32, 33, 34,*E,* 35,*E,* and 36,*D.*)

Throughout the transitional zone, definable forms occur. These forms may occupy a relatively large area or be limited to comparatively small patches. In the northwest corner of New Mexico, all plants belong to a form that the writer refers to as Aztec type. This type differs from described members of the *Y. glauca* alliance in that its leaves, inflorescences, and flowers are shorter and smaller than other members of the group. It is similar to *Y. angustissima* in its large, open clump and constricted capsules. It resembles *Y. glauca* and *Y. baileyi* variety *navajoa* in that its flowers extend well into the leaves. A second form, referred to as the Albuquerque type, occupies a narrow zone along the Rio Grande south of Albuquerque. These plants differ from those in the eastern part of New Mexico mainly in their smaller, denser clump; their white rather than green basic flower color, and their smaller, mainly constricted capsules. The type is more variable than the Aztec type. In the vicinities of Nara Visa and Pasamonte, N. Mex., large areas of late-flowering plants are common. These plants not only flower 2 or 3 weeks later than the majority of plants in northeastern New Mexico, but require approximately 2 more weeks to complete flowering. They have larger and more branched inflorescences than other members of the *Y. glauca* alliance, and possibly represent a third form. Other possible forms, such as subcaulescent, short or narrowleaved types, are scattered throughout the transitional zones, but these forms are more variable and do not occur in concentrations of appreciable size.

Relative to *Y. glauca,* Trelease *(31, p. 60)* stated that the inflorescence is ". . . almost invariably marked by a simple inflorescence, not carried on a scape above the cluster of leaves." He described the capsules as large, oblong, and usually not constricted. Trelease's illustration (*his pl. 24, 1* and *2*) of capsules of *Y. angustissima* from near Grand Canyon, Ariz., and of *Y. glauca* from Manitou, Colo., are typical of the types. His plate of *Y. glauca* (*pl. 23, 2)* near Albuquerque, N. Mex., appears to have mainly constricted capsules. With regard to *Y. angustissima,* Trelease *(31, p. 58)* stated, "In habit, this species . . . recalls the narrow-leaved form of *Y. glauca* as found, for example, about Albuquerque, N. Mex., . . . it differs in its more frequently branched inflorescence, oblong (white?) style, and smaller capsule and seed . . ." The plants in the vicinity of Albuquerque are extremely variable and more or less midway between *Y. glauca* and *Y. angustissima.* Although plants with simple inflorescences predominate, those with branched ones are plentiful, and it would be difficult to find typical *Y. glauca* capsules in the vicinity. Furthermore, no plants in the vicinity of Albuquerque have the tumid, dark-green style characteristic of *Y. glauca.*

With respect to *Y. angustissima* and *Y. baileyi* Benson and Darrow *(3, p. 66)* stated, " . . . they may be merely transitional forms between this [*glauca*] and *Yucca elata* . . . Intermediate types between these forms and *Yucca elata* are found along the southern limits of the range in Arizona." Since the characteristics of these intermediate types are quite distinct from the differences between *Y. glauca* and other members of the *Y. glauca* alliance, the writer does not believe that *Y. elata* was involved in the origin of any member of the *Y. glauca* alliance.

Between the range of *Y. glauca* and the ranges of *Y. angustissima* and *Y. baileyi* McKelvey (*25, p. 117*) separated *Y. intermedia.* She characterized her species thus: " . . . inflorescence is a tall, vigorous, simple raceme but a raceme with one to several short, basal branchlets is not unusual and a true panicle is

occasional throughout the plant's range; the inflorescence proper starts among or immediately above the foliage; the plant forms small to medium size clumps with but few heads of leaves." According to McKelvey, the species differed from *Y. glauca* in its more tidy appearance and in its cylindric, white or pale-green style; from *Y. baileyi* (*Y. standleyi* McKelvey) in its less rigid, less filiferous leaves, which do not approach triquetrous; in its head of leaves (*Y. standleyi,* hemispherical) that is constricted below and spreading above; and in its considerably longer more branched inflorescence; and from *Y. angustissima* in its larger, less constricted capsules, which have stronger, thicker walls, darker rougher epidermis, etc.; in its longer inflorescence (1.5 m. as against 1.3 m. or usually less), which has a greater tendency to branch; and in its slightly longer and somewhat heavier pistil.

In central New Mexico, McKelvey (*25*) separated *Y. intermedia* variety *ramosa* from the species by greater vigor of plant, foliage, and inflorescence. In characterizing the variety McKelvey *(p. 120)* stated, "Inflorescence on young plants sometimes racemose or again with a few basal branchlets, on large, mature specimens usually much branched from base upward, . . ." and, ". . . the inflorescence is, for the most part, a large, broad panicle, branched for the greater part of its length, but from this form we also note occasional gradations to the simple but vigorous raceme."

In all yuccas the size and shape of the leaf head is largely determined by its age and the amount of rainfall. The inflorescences of young plants are usually more branched and vigorous than those of matured plants. None of the characters separating *Y. intermedia* are characteristic of only the species. They appear to be combinations of the characters of members of the *Y. glauca* alliance. All characteristics of variety *ramosa,* especially that of McKelvey's description of the inflorescence, strongly suggest an intermingling of *Y. elata* and members of the *Y. glauca* alliance. Transitional plants similar to *Y. intermedia* are shown in plates 38, 39, and 48, and plants similar to variety *ramosa* are discussed under *Y. elata* and shown in plates 40 and 41.

The panicles of *Y. constricta* are pyramidal or short and broadly conoidal in shape. They usually have between 8 to 15 branches, which vary from 10 to 40 cm. in length. The inflorescence of *Y. glauca* is mainly racemose, or at the most has 4 short, abortive branchlets toward the base. The flowers and capsules of *Y. glauca* are considerably larger than those of *Y. constricta,* and the capsules of *Y. glauca* are seldom constricted, whereas those of *Y. constricta* are commonly deeply constricted. Within the area between McCamey, Junction, Lamesa, and Abilene, Tex., plants gradually change from *Y. glauca* in the north to *Y. constricta* toward the southeast.

This transition mainly involves the change of large, open clump, slender, weak, tall inflorescence, panicle, and long scape, characteristic of *Y. constricta,* at Uvalde, to small, dense clump, stout short inflorescence, raceme, and short scape of *Y. glauca* at Hadley, Tex. In the center of this area, between Runnels and Upton Counties, the majority of plants are midway between *Y. glauca* and *Y. constricta,* but plants resembling either species in one or more characters are not uncommon. Plants with racemose and paniculate inflorescences occur in approximately equal numbers. The panicles are raggedly pyramidal in shape and have from 8 to 15 branches that are 10 to 35 cm. long. The majority of flowers and capsules appear to be intermediate in size, and the capsules are only moderately constricted. The styles are pale green or white, slender or somewhat swollen toward the center. North of Runnels and Upton

Counties, the plants become more like *Y. glauca,* but scattered intermediates or plants resembling *Y. constricta* in one or more characters spread well into the western part of the *Y. glauca* alliance transitional zone. In New Mexico plants that resemble intermediates are fairly common in the vicinities of Lingo and Bluit, and they extend as far north as Tucumcari and Mosquero. South of Runnels and Upton Counties, the plants rapidly approach *Y. constricta.* However, variable plants, possibly showing the influence of either *Y. glauca* or *Y. elata,* are found in the vicinities of Ozona and Del Rio, Tex. These plants have somewhat shorter flowering stalks (averages of 1.1 and 1.8 m., respectively), shorter scapes (0.8 and 0.95 m.), and larger and less constricted capsules. In the northwestern and somewhat in the southwestern part of the zone, transitional forms involving *Y. elata* are rather common.

McKelvey (*25*) cited several apparent hybrids between *Y. constricta* and *Y. rupicola.* Under *Y. reverchoni,* possible *Y. rupicola* × *Y. constricta-glauca* hybrids are discussed. These plants mainly resembled (1) *rupicola,* but had small, greenish, globose flowers, with short styles like *Y. glauca-Y. constricta;* or (2) *Y. glauca,* but had nonfiliferous, frequently somewhat denticulate leaves similar to those of *Y. rupicola.*

In addition to the foregoing associations, members of the *Y. glauca* alliance are occasionally admixed with the capsular-fruited species *Y. neomexicana* and *Y. elata* and the fleshy-fruited species *Y. torreyi, Y. baccata,* and *Y. treculeana.* Possible hybrids between *Y. elata* and members of the *Y. glauca* alliance are discussed under *Y. elata.* No evidence of hybrids between capsular- and fleshy-fruited yuccas has been found.

21. *Yucca elata*

(Palmella, soapweed, or soaptree)

Yucca elata Engelm., Bot. Gaz. 7: 17. 1882.

Yucca angustifolia var. *radiosa* Engelm., *in* King, U. S. Geol. Expl. 40th Par. Rpt. 5: 496. 1871.

Y. angustifolia var. *elata* Engelm., St. Louis Acad. Sci. Trans. 3: 50. 1878.
Y. radiosa (Engelm.) Trel., Mo. Bot. Gard. Ann. Rpt. 3: 163. 1892; 13: 56. 1902.

Plant caulescent or arborescent, solitary but soon clumped; clump small (0.5 to 2.5 m., or rarely up to 4.0 m. in diameter), fairly open (0.3 to 1.2 heads of leaves and stems per square meter); stems mainly 0.9 to 4.5 m. tall, trunklike, erect, with 1 to 5 short, assurgent branches toward the top, or rarely unbranched and up to 7.8 m. tall; head of leaves large, symmetrical; leaf blade commonly 30 to 95 cm. long, 0.4 to 2.5 cm. wide, linear, plano-convex or plano-keeled, striate, rigidly divergent, flexible, pale green; leaf margin white or greenish white, soon finely filiferous; flowering stalk 1.0 to 5.4 (2.9) m. tall, scape 0.9 to 3.0 (1.4) m. long, stout, mainly 2.5 to 6.5 cm. in diameter, rarely up to 12.0 cm. in diameter, greatly exceeding the foliage; panicle 0.5 to 3.5 (1.3) m. long, 0.3 to 0.6 m. in diameter, with 20 to 45 branchlets, ellipsoidal or broadest toward center; flowers many, campanulate or somewhat globose, white or cream, rarely greenish or tinged with pink, perianth segments narrow-elliptical to broad-elliptical or even ovate, acute; sepals 32 to 57 (43.8) mm. long, 14 to 27 (19.6) mm. wide, petals 34 to 57 (44.8) mm. long, 20

to 35 (27.8) mm. wide; filaments 16 to 30 (20.6) mm. long, slender; pistil 22 to 33 (26.8) mm. long; ovary 6 to 10 (8.2) mm. in diameter, slender, white or pale green, oblong-cylindrical, abruptly terminating in style, with deep carpel sutures and anther depressions prominent or wanting; style 6 to 11 (8.8) mm. long, shape variable, slender and oblong-cylindric or stoutish, white or pale green; capsule 40 to 70 (52) mm. long, 35 to 58 (47) mm. in diameter, oblong-cylindric, mucronate, commonly symmetrical, rarely constricted; seed 7 to 10 by 9 to 14 mm., thin, dull black, with broad marginal wing. (Pls. 37, *A-C,* 49, and 50.)

TYPE: Extending from west Texas to Utah, Arizona, and northern Mexico, *J. T. Rothrock 382,* 1874, U. S. Natl. Herbarium No. 35891. Lectotype: McKelvey, Camp Grant, Graham County, Ariz.

RANGE: Within the United States, *Yucca elata* has two well-separated ranges. The larger range forms a wide belt extending from Pecos County, Tex., northwest and west through southern and south-central New Mexico to north-central Yuma County and south-central Maricopa County, Ariz. The second range is a relatively small one, occurring in western Washington and Iron Counties, Utah. Although the species is usually scattered, it frequently forms dense concentrations covering many square miles. Within the large southern belt *Y. elata* occurs on gently sloping deserts and desert grasslands, at 1,500 to 6,000 feet elevation, and usually flowers between the first of June and the middle of July.

Yucca elata is a well-defined species that may easily be recognized by its (1) well-developed trunklike stem; (2) small, open clump of few heads of leaves; (3) long, flexible leaves, with filiferous margins, (4) tall flowering stalk with large, ellipsoidal panicle; and (5) capsular fruit. However, in the northern limits of its range, plants of the species frequently appear weak and degenerate. Such plants are particularly common in New Mexico, especially between Picacho, Lincoln County, and Elkins, Chaves County, and between Ancho, Lincoln County, and Claunch, Socorro County. These plants rarely form a clump, and their stems are slender, frequently leaning or procumbent, and rarely over a meter long. The heads of leaves are small, with but a few short leaves. On the other hand, vigorous, normal-sized plants of the species have been observed as far north as Pima, Ariz.

Although *Y. elata* is quite variable throughout its range, in several localities the variations are characteristic of the majority of plants. These plants may possibly represent forms of the species. In Guadalupe Pass, Tex., the plants are nanate with stems 0.15 to 1.0 m. tall; leaf blades very rigid and filiferous, 2 to 8 mm. wide and 15 to 35 cm. long; and flowering stalk 0.7 to 1.5 m. tall. The majority of yuccas between Aguila and Salome, Ariz., have very dense panicles, with thin, papery capsules. In the vicinity of Pecos, Tex., plants of *Y. elata* commonly have capsules in which the dorsal suture separates at the apex, forming a peculiar open pocket. South of Orogrande, N. Mex., and elsewhere in sand dune areas, the clumps are quite large, with many heads of leaves and comparatively short stems.

Scattered throughout the New Mexico and Texas ranges of *Y. elata,* occasional cases of phyllody *(7)* occur. They are particularly common in the concentrations east of Van Horn, Tex.

In 1878 George Engelmann (*12*) reported *Y. elata* (*Y. angustifolia* var. *elata*) as extending from western Texas to Utah, Arizona, and northern Mexico. In 1881 he (*13*) described *Y. elata* as having trunks 3 to 5, or even 11, feet tall, a large-branched panicle, and expanding flowers. At the same

time he limited the species range to the deserts of Arizona and probably southern New Mexico and made no reference to the Utah plants. The plants in the Santa Clara Valley, particularly those near Saint George, were provisionally referred to as *Y. elata* by Merriam (*26, p. 358*) and as *Y. radiosa* (synonym of *Y. elata*) by Coville (*10*).

McKelvey (*25*) separated the Santa Clara Valley plants as a new species, *Y. utahensis,* and reported its range as, "Plentiful in Washington Co., Utah; extending thence into northwestern Arizona and possibly into Lincoln Co., Nevada, near Panaca."

In Washington, southeastern Iron, and eastern Kane Counties, Utah, the yuccas are extremely variable and confusing. The larger part of this area, along the Santa Clara and Virgin River basins, is a relatively low (2,500 to 5,000 feet), warm valley. The soil in the valley varies from a medium-coarse gravel to a light sand, which occasionally forms dunes. Although the valley is surrounded by mountains frequently covered with snow, snowfall in the valley is very light and rarely remains on the ground for any length of time. The rest of the area, extending east from the valley through Zion National Park into eastern Kane County, is quite mountainous. In eastern Kane County, the yuccas extend south from the vicinity of Long Valley (approximately 6,500 feet elevation) to the Arizona border (around 4,500 feet). Here they are mainly on steep mountain slopes, on deep well-drained gravel soil, or rarely (10 miles north of Kanab) in sand dune patches. It is the writer's opinion that the majority of yuccas in the warmer valley constitute a remote stand of *Y. elata,* which at present is represented by poor or degenerate plants and hybrids between the latter species and *Y. angustissima.* The yuccas in the mountainous eastern part of the area are typical *Y. angustissima* and possible *Y. angustissima-Y. elata* hybrids or derivatives of such hybrids. These hybrids extend south from Kanab into Arizona, where only typical *Y. angustissima* occurs.

A description of *Y. elata* in the Santa Clara and Virgin River basins is as follows: Plant subcaulescent, solitary or small open clump with 3 to 8 heads of leaves; stem 0.3 to 2.0 m. tall, trunklike, slender, weak; scape 0.7 to 1.5 m. long; flowering stalk 1.5 to 2.5 m. tall; panicle 0.8 to 1.2 m. long, ellipsoidal, amply branched; sepals 28 to 40 (35.4) mm. long, 13 to 22 (16.6) mm. wide; petals 30 to 43 (37.0) mm. long, 18 to 28 (23.5) mm. wide; filaments 16 to 24 (20.3) mm. long; pistil 23 to 29 mm. long; ovary 5 to 7 (6.1) mm. in diameter, stout, pale green or white, oblong-cylindrical, abruptly terminating in style, with well-marked carpel sutures and anther depressions; style 7 to 11 (8.8) mm. long, oblong, very pale green or white; capsule 4 to 6 cm. long, 2.0 to 3.5 cm. in diameter, oblong-cylindrical, rarely constricted.

Although as a general rule the average measurements in the plants above are somewhat smaller than those given in the preceding description of *Y. elata,* all characters are well within the range of typical *Y. elata.* As in the case of plants in the main *Y. elata* belt, those plants growing on the coarser gravelly slopes are mainly long stemmed, whereas those in the sandy regions are shorter stemmed and more clumped. In the Utah range, the former plants usually have 1 to 3 weak stems, which are rarely over a meter tall. Along the washes, and in the more protected areas, however, plants with stems up to 1.3 m. tall occasionally occur. A few miles south of Pintura, one exceptionally strong, single-stemmed plant was 1.9 m. tall and had 3 branches and 2 old inflorescences. The inflorescences were typical of *Y. elata* and had rather small, nonconstricted capsules. In many respects these plants are similar to the weak

ones found along the northern part of the main *Y. elata* belt in New Mexico. The more clumped plants are similar to those found in the sandy regions of Orogrande, N. Mex.

Apparent Hybrids of *Yucca elata* and *Yucca glauca* Alliance

Yucca intermedia var. *ramosa* McKelvey, Yuccas Southwest. U. S. 2: 120. 1947.

Yucca utahensis McKelvey, Yuccas Southwest. U. S. 2: 94. 1947.
Y. verdiensis McKelvey, Yuccas Southwest. U. S. 2: 98. 1947.
Y. campestris McKelvey, Yuccas Southwest. U. S. 2: 173. 1947.
(?) *Y. kanabensis* McKelvey, Yuccas Southwest. U. S. 2: 122. 1947.

Along the northern border of its New Mexico and Arizona range and in its Utah range, *Yucca elata* appears to hybridize freely with members of the *Y. glauca* alliance, and plants exhibiting characteristics of both *Y. elata* and members of the *Y. glauca* alliance are common. Scattered plants toward the southeastern limits of the range of *Y. elata,* particularly from Pecos County northeast to Howard County, Tex., have characters of both *Y. elata* and *Y. constricta.* The main transitional zone roughly extends along an imaginary line from Lovington, N. Mex., to Prescott, Ariz., and varies from 25 to 65 miles in width. The majority of transitional forms within this zone may be roughly placed into the following groups: (1) *Y. angustissima* large, open acaulescent or subcaulescent clump resembling *Y. elata,* with similar tall flowering stalk and ample, branched, ellipsoidal panicle (pl. 51); (2) acaulescent or subcaulescent, solitary, or small clump, with tall, strong, flowering stalk and long raceme (pl. 38); and (3) caulescent, solitary, or small clump, with rather short, weak, flowering stalk and fairly long raceme (pl. 39).

Along the Rio Grande basin, the transitional zone is extremely wide and clearly shows the transition between *Y. elata* and *Y. glauca* (or *Y. baileyi*). Plants with *Y. elata* characters, or characters apparently influenced by *Y. elata,* are found as far north as Albuquerque; whereas plants showing the influence of *Y. glauca* extend as far south as Las Cruces, N. Mex. The northern *Y. glauca* plants influenced by *Y. elata* are mainly recognized by the vigorous inflorescence that is usually borne above the foliage and somewhat branched, and occasionally by a true, ellipsoidal panicle. The plants usually form a small, dense clump with only a few heads of leaves, and occasionally they have typical *Y. elata* rhizomes. The *Y. elata* plants influenced by *Y. glauca* in the south are mainly recognized by the weak inflorescence that is rather low, usually somewhat branched, and frequently a true raceme. The plants are usually weak and short-stemmed.

Approximately 22 miles north of Socorro, N. Mex., on a bluff overlooking the Rio Grande, is an excellent patch of yuccas. The patch probably extends 1.5 to 2 miles along the bluff and is about 0.75 mile wide. It is within the range of *Y. intermedia* variety *ramosa* (p. 58). The plants in this field are extremely variable, and neither typical *Y. glauca* nor *Y. elata* plants occur. The plants are solitary or in small clumps with 2 to 8 heads of leaves. They are commonly acaulescent, but occasionally subcaulescent with trunklike stems 30 to 46 cm. tall. The majority of stemmed plants have large heads of leaves, whereas the heads of strictly acaulescent plants are usually rather small. Most of the inflorescences are strong and tall, and only 25 percent of them are branched.

Among these branched plants slightly branched panicles predominate, but panicles similar to those of *Y. elata* are not uncommon. Measurements in this field are as follows: Flowering stalk 70 to 155 (120) cm. long; scape 16 to 74 (51) cm. long; panicle or raceme 33 to 100 (69) cm. long; sepals 12 to 23 (18) mm. wide, 28 to 53 (38) mm. long; petals 20 to 32 (27) mm. wide; 30 to 53 (40) mm. long; filaments 16 to 25 (21) mm. long; pistil 19 to 31 (26) mm. long; ovary 5 to 11 (7) mm. in diameter; and style 5 to 10 (8) mm.

The average of *Y. elata* and *Y. glauca* inflorescence measurements closely approaches the measurements of the inflorescences in this field. The measurements of the flower parts are considerably smaller than those of *Y. glauca* and slightly smaller than those of *Y. elata.* There is no difference between the size of the flowers from panicles resembling *Y. elata* and from racemes resembling *Y. glauca.* Although the styles are mainly oblong-cylindric, they vary from slender to quite stoutish and from very pale green to fairly dark green. The capsules average 59 mm. long and 35 mm. in diameter, and approximately 60 percent of them are slightly constricted. In all respects these plants are what would be expected in a field of hybrids and segregating generations of crosses between *Y. elata* and *Y. glauca.* (Pls. 39, 40, and 41.)

In central and east-central Arizona, particularly in the vicinities of Whiteriver, Show Low, and Springerville, and in the Santa Clara and Virgin River basins of Utah, similar apparent hybrids occur. In several characters, however, especially in their large open clump and small, deeply constricted capsules, these plants resemble *Y. angustissima* rather than *Y. glauca* (pl. 51). It is the writer's opinion that McKelvey's species *Y. verdiensis,* Arizona, and *Y. utahensis,* Utah, belong to this group of apparent hybrids between *Y. elata* and *Y. angustissima.*

McKelvey (*25, p. 98*) distinguished *Y. verdiensis* thus: "Plants acaulescent to caulescent, forming a single head or small, congested clumps with several heads; stem at most short, hidden beneath reflexed leaves . . . Inflorescence 2.1-2.7 m. in length overall (scape longer than flowering portion); inflorescence proper panicled, raised high above leaves, 1-1.3 m. in length, rarely branched throughout, usually with a few long, wide-spreading basal branchlets . . . " McKelvey recognized the similarity between *Y. verdiensis* and *Y. angustissima* and stated (*p. 102*), " . . . the capsules of both are small, with thin wall, smooth epidermis and, at or after dehiscence, the side of the locules show a tendency to twist which is not common in other species; the foliage of both averages slender. *Yucca verdiensis* seems to range mainly southeast of *Y. angustissima* and one wonders whether it might perhaps represent a panicled, mountain variety of the racemose desert plant. However, its small flowers with extremely small and slender pistil and its very long scape, which raises the panicled flowering portion high above the leaves, bear no resemblance to those of *Y. angustissima.*"

McKelvey (*25, p. 98*) also stated, "*Yucca utahensis* comes closest to *Y. elata* probably, but its often much broader and more concave leaves, non-arborescent and large clump habit, and, for the most part, smaller flowers with usually extremely slender style, separates it from that species." She described (*p. 94*) *Y. utahensis* thus, "Plants acaulescent or more often with procumbent stems 0.6-1.3 m. in length, forming large clumps with 10-15 heads of leaves." She wrote that it prefers a fine, red sandy soil. Of *Y. elata* in sandy soil near Van Horn, Tex., McKelvey reported (*p. 93*), " . . . plants were mainly of clump-habit, with numerous short stems and heads of leaves, . . . sending up

many inflorescences, sixteen were counted on one plant." The writer has not found the leaves of the plants in the Santa Clara and Virgin River basins to be broader or more concave than those found in many *Y. elata* areas or as concaved as the leaves of the plants (*Y. kanabensis*) in the sand dunes north of Kanab, Utah.

Thinly scattered from Pecos County northeast to Howard County, Tex., and northwest into southern New Mexico, and possibly well into northwestern New Mexico are plants that appear to be *Y. elata-Y. constricta* hybrids and hybrids segregates. A brief description of these variable plants is as follows: Plant an open or rarely rather dense, large acaulescent or subcaulescent clump, with stems occasionally a meter in length; head of leaves large, spreading; flowering stalk 0.5 to 1.8 m. tall; scape 0.2 to 0.9 m. long, stout; panicle usually well above foliage but not uncommonly extending into foliage, ellipsoidal, ovoid, or oblate-ovoid; perianth segments 41 to 65 mm. long, 23 to 40 mm. wide, pistil 26 to 30 mm. long; ovary 5 to 9 mm. in diameter, stout-ovoid, pale green; style slender or rather stout, pale to rather dark green; capsule large to small, symmetrical or constricted. The open clump of these plants resembles that of *Y. constricta.* Although the stems in subcaulescent plants are considerably shorter than those of *Y. elata,* they are two to three times the length and much stouter than those of *Y. constricta.* Although the heads of leaves are similar to those of either species, the marginal fibers of the leaves are fine and soon erode away as in *Y. constricta.* The inflorescence is stout, well branched, and usually similar in shape to that of *Y. elata.* Occasionally, however, it is broadest toward the base as in *Y. constricta.* Perhaps one of the most confusing characteristics of the plants is the variable height of the panicle, which is never as high as in either *Y. elata* or *Y. constricta* and which occasionally extends well into the leaves. The latter character, as well as that of the variable color of the style, suggests the possible entrance of *Y. glauca* into the hybrid complex. Such plants are not unlike the possible *Y. elata-Y. glauca* hybrids described in the Rio Grande field (p. 62). Although the flowers of the apparent *Y. elata-Y. constricta* plants could be from either *Y. elata* or *Y. constricta,* their ovaries more closely resemble *Y. elata* in size. The capsules are frequently as large and symmetrical as those of *Y. elata* and commonly as small and constricted as in many *Y. constricta* plants. Several miles east of Pecos, Tex., the writer found plants resembling *Y. constricta* with large symmetrical capsules that were indistinguishable from those of *Y. elata,* whereas a few miles east of Pecos, *Y. elata* plants had capsules similar to those of *Y. constricta.*

McKelvey (*25*) separated these apparent *Y. elata-Y. constricta* hybrids as *Y. campestris* and gave their relationship as close to *Y. glauca.*

In the writer's opinion *Y. utahensis, Y. verdiensis,* and *Y. campestris* are very similar to each other and frequently indistinguishable from many of the apparent *Y. elata-Y. glauca* alliance hybrids. Many of the distinguishing characters of the three species are well within the range of the characters of *Y. elata* or members of the *Y. glauca* alliance.

Spreading north and southwest from eastern Zion National Park, Utah, are plants that appear to be a giant form of *Y. angustissima.* The inflorescences of these plants are mainly racemiform or with a few short abortive branchlets and are from 1.8 to 2.5 m. in length. The flowers are large and the ovary somewhat larger and style somewhat shorter than those of *Y. angustissima.* The capsules are large, rough, and usually slightly to rather deeply constricted. Although these plants commonly form a rather open, small, acaulescent clump, in the

sand dunes north of Kanab, Utah, the clumps are large, dense, and frequently subcaulescent, with short procumbent stems.

McKelvey *(25, p. 122)* separated the above plants as *Y. kanabensis*. Specimens of similar plants have been collected in northern Mohave County, Ariz., by R. H. Peebles and Harvey W. Parker, 1940 (pl. 48), and J. Penchney Hester [21] reported the plants as occurring from Short Creek to Fredonia, Ariz., and to Kave Creek, Utah. Kearney and Peebles (*20*) referred to the plants as a form of *Y. angustissima*. Although the plants possibly represent a species or type, they are very similar to plants occurring in transitional zones between *Y. elata* and *Y. glauca* alliance, even as far removed as the Rio Grande basin (pls. 38 and 39).

In Texas *Y. elata* is occasionally associated with, or in close proximity to, *Y. rostrata, Y. thompsoniana,* and *Y. reverchoni,* whereas in Utah it is close to the range of apparent *Y. neomexicana-Y. gilbertiana* hybrids. No evidence of hybrids between *Y. elata* and these yuccas has been observed, nor has evidence been found that *Y. elata* hybridizes with any of the fleshy-fruited species with which it commonly intermingles.

THE YUCCA MOTH, POLLINATION, AND FERTILITY

The remarkable association of the yucca moths (mainly *Tegeticula yuccasella* (Riley) and *Prodoxus quinquepunctellus* (Chambers)) with the yucca plant has been known for many years. It is reported that the moth collects pollen from several flowers, carries it to another flower, and forces it down the stigmatic tube. While forcing the pollen down the stigmatic tube, the moth thrusts its ovipositor through the ovary wall and lays eggs. Thus the flower is sure of being pollinated and of producing seed, upon which the larvae from the eggs feed. Usually the larvae consume only a small part of the seed produced. If the association of the moth and yucca proceeds normally, definite stages in the life cycles of the two will coincide. Very little data relative to whether the yucca depends entirely upon the moth for pollination, whether pollination is actually cross-pollination (between two plants), and whether an interference in their respective life cycles offset either the moth or plant have been available. Since the activities of the moths undoubtedly have an important role in the great diversity and distribution of yucca, it appears desirable to record some of the writer's observations bearing upon them.

In yucca concentrations there are usually several yucca moths in practically all open flowers, and a single inflorescence generally contains a dozen or more moths. Early in the summer of 1942 the writer found that *Yucca elata* along highway U.S. No. 180 from El Paso, Tex., to Carlsbad, N. Mex., was well in flower and that the majority of inflorescences as far east as Cornudas, Tex., contained numerous moths. East of Cornudas, however, the moths decreased in number until, between the vicinities of Salt Flat and Pine Springs, Tex., no moths were found. Although from Pine Springs to Carlsbad, N. Mex., *Y. elata* is quite thinly scattered, all inflorescences were amply supplied with moths. In the fall of the year the plants were again examined and it was found that fruiting occurred only in the areas where the moth was present.

[21] Notes on Hester's specimen No. 678, of leaves and fruit, dated October 1944, in U. S. Dept. Agr. Herbarium, Sacaton, Ariz.

In 1942 only a few scattered plants in the dense concentration of *Y. glauca* around Quay, Tucumcari, and Logan, N. Mex., flowered. All of the flowers of these plants were heavily infested with yucca moths. In the fall of the year, the few flowering stalks were heavily burdened with fruit, but seed damage by the moth's larvae was exceptionally high. During the spring of 1943 the concentrations flowered profusely, and, although all inflorescences contained a few moths, they appeared to be quite limited in number. Numerous flowers were found without moths, and many inflorescences contained only one or two moths. In the fall of 1943 it was noted that fruiting was exceptionally light in these concentrations. During the years of 1944 and 1945 flowering and fruiting in the concentrations appeared to be quite normal.

In the writer's nursery approximately 15 plants have flowered, and each was in flower at the same time that 3 or more other plants were flowering. There are no yucca moths in the nursery, and, except in the case of *Y. whipplei* and of hand-pollinated flowers, no fruits set. Table 2 gives the results of hand-pollinations of several yucca species and forms in the nursery.

Table 2 represents 977 pollinations, of which 21.51 percent set fruit containing numerous apparently viable seed. In both selfed and cross-pollinated plants, the fertility varied from 0 to 93.34 percent. A total of 225 self- and 752 cross-pollinations were made, which, respectively, set 24.89 and 21.81 percent fruit. Of the pollinations between apparent hybrids 53.33 percent set fruit, while only 6.57 percent of the pollinations between typical species set fruit. Seventeen percent of the pollinations between apparent hybrids and species set fruit. Although these percentages indicate that the plants are about equally self- and cross-fertile, it is evident that the apparent hybrids are considerably more fertile than the species.

Table 2 reveals that *Y. arizonica, Y. neomexicana, Y. elata, Y. reverchoni, Y. rupicola, Y. thompsoniana,* and the apparent hybrids *Y. thompsoniana* P 3 and *Y. glauca* 11-2 are self-sterile or nearly so. Although *Y. neomexicana, Y. reverchoni, Y. rupicola, Y. thompsoniana* P 1, and *Y. elata* are nearly female-sterile, they are highly male-fertile. *Y. schidigera* and the apparent hybrids *Y. glauca* 11-1 and *Y. constricta* are rather highly self-fertile, whereas the last two plants and apparent *Y. thompsoniana* P 3 hybrid are just as highly male- and female-fertile.

There appears to be little or no correlation between the relationships of the species and the results of cross-pollinations. In the majority of crosses between the baccate- and capsular-fruited yuccas, the baccate-fruited species was mainly used as the staminate parent. The only crosses employing the baccate-fruited species as the pistillate parent are *Y. arizonica-Y. glauca* apparent hybrid and *Y. arizonica-Y. neomexicana;* 50 and 70 percent, respectively, of these crosses set fruit. Within the capsular-fruited species *Y. neomexicana* crosses readily with the distantly related apparent hybrids of *Y. glauca* and *Y. constricta,* and *Y. thompsoniana* likewise easily crosses with remotely related *Y. elata-Y. glauca* apparent hybrid, and *Y. constricta* apparent hybrid. Trelease (*31*) cited several garden hybrids within the capsular-fruited species *Y. filamentosa* and lists several artificial hybrids between the latter species and the baccate-fruited species *Y. gloriosa.*

Although several of the yuccas listed in table 2 commonly or always have constricted fruit, none of the hand-pollinations resulted in constricted fruit. Unquestionably the yucca moth is responsible for the occurrence of constricted fruit in native plants. It is very probable that the constrictions are caused by the failure of the injured ovules to develop.

In the spring of 1950 two plants of *Y. whipplei* obtained from the badlands, northwest of Eden Hot Springs, Riverside County, Calif., flowered in the nursery. These plants were adjacent to each other and flowered simultaneously. Throughout the flowering period no yucca moths were found in the nursery. One of the plants fruited profusely, and every capsule was completely filled with seed. No capsule or seed showed any signs of the yucca moth or larvae having been present. Pollination had undoubtedly been caused by insects other than the yucca moth, which were abundant in the flowers. Although it is not known how general such pollination occurs in *Y. whipplei,* it is very likely quite common, as *Y. whipplei* is the only yucca with a capitate stigma. The second plant failed to set fruit and died shortly after flowering. On several occasions the writer has observed similar fruiting and nonfruiting plants of *Y. whipplei* in the badlands section, as well as in the foothills on the San Bernardino and the San Gabriel Mountains. The cause of the apparent sterility is unknown.

Of the flowers of the yuccas in table 2, only the hand-pollinated ones set fruit, which indicates that many if not all of our southwestern yuccas except *Y. whipplei* depend upon the yucca moth for pollination and consequently the development of fruit and seed. When the yuccas over a wide range flower sparsely, it is apparent that the moth's lack of breeding places and the limited food supply for the larvae greatly reduces the moth population. Possibly the lack of moths between Salt Flats and Pine Springs, Tex., in 1942 indicates that the plants failed to flower in 1941, and the moth population in the region was obliterated. Following a reduction in moth population, it is apparent that recovery to a balanced condition of flowering, fruiting, and moth infestation would depend upon the degree of reduction and the size of the area involved. However, mothless or nearly mothless areas covered a relatively small part of the range of a yucca species, and it is very likely normal flowering, fruiting, and moth infestation would be recovered in several years.

Outside of *Y. brevifolia* and *Y. whipplei,* our southwestern yuccas are not reproducing to any extent by seeds. There can be little question, therefore, that the yucca moth is more dependent on the yucca for its existence than the yucca is on the moth. During their long life through vegetative reproduction, the majority of yuccas would continue to exist for many years without the moth. On the other hand, it appears that the yucca moth would be completely wiped out if the yuccas failed to flower for a single year.

Regardless of the fact that yuccas are about equally self- and cross-fertile and that the moth flies from flower to flower, it is doubtful if cross-pollinations are as prevalent as reported. It is very likely that the number of self-pollinated flowers far exceeds the number of cross-pollinated ones, and except in areas where species are admixed and flower at the same time interspecific crossing is but remotely possible.

YUCCA SEEDS AND SEEDLINGS

The seeds of southwestern yuccas may roughly be separated into four morphological types, which, in the majority of species, are characteristic of the sections of the genus. In the indehiscent-fruited species the seeds of section Sarcocarpa are flat, thick (2 to 3 mm.), rough-surfaced, wingless, and oval or circular in outline, whereas those of section Clistocarpa are flat, thin (rarely up to 1.5 mm. thick), smooth-surfaced, wingless, and irregularly oval in shape.

TABLE 2.—*Percentage of matured fruit obtained from self- and cross-pollinations in yucca made in the U. S. Department of Agriculture yucca nursery at Riverside, Calif., in May and June 1949*[1]

Pistillate parent	Staminate parents														
	Y. arizonica P 1	*Y. arizonica* P 2	*Y. schidigera*	*Y. glauca* hyb. ? No. 11–1	*Y. glauca* hyb. ? No. 11–2	*Y. glauca* hyb. ? No. 19–1	*Y. glauca* hyb. ? No. 19–2	*Y. neomexicana*	*Y. thompsoniana* P 1	*Y. thompsoniana* hyb. ? P 3	*Y. constricta* hyb. ? P 1	*Y. constricta* hyb. ? P 2	*Y. reverchoni*	*Y. rupicola*	*Y. elata*
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Y. arizonica P 1	0	0	0			[2]50.00		[2]70.00							
Y. arizonica P 2	0	[2]10.00	0												
Y. schidigera	0		26.67												
Y. glauca hyb. ? No. 11–1				66.67	73.34				93.34			66.67	[3]0		
Y. glauca hyb. ? No. 11–2			0	54.45	0			14.45	20.00			66.67			
Y. glauca hyb. ? No. 19–1		6.67	0			[2]30.00		[4]16.67							
Y. glauca hyb. ? No. 19–2							66.67								
Y. neomexicana		0	0			0		[3]8.00	0						
Y. thompsoniana P 1			0	6.67				[5]0	[6]0	0	20.00	0	6.67		6.67
Y. thompsoniana hyb. ? P 3										0				73.34	

Y. constricta hyb. ? P 1			14.45		73.34			6.67	54.45		93.34	86.67			66.67
Y. constricta hyb. ? P 2			0	20.00	6.67				40.00		93.34	60.00	20.00		
Y. reverchoni						0						0	14.45		
Y. rupicola															
Y. elata									0			6.67	0	14.45	6.67

[1] All plants, except *Y. schidigera*, are briefly described on pp. 73 to 75. *Y. schidigera* was a typical plant growing on Mount Rubidoux, adjacent to the nursery. Pollinations were made by applying the pollen to the stigma with the filament. The dehiscent anther was forced between the stigma lobes, where it was easily broken off by a slight twist of the filament. In all cases the anther remnants, as well as the pollen remained on the stigma, or frequently, slightly down the style tube. All percentages, or lack of percentages (0), except otherwise noted, are based upon 15 pollinations. Abundant, apparently good seed was obtained from all fruit.

[2] Based upon 10 pollinations.

[3] Based upon 25 pollinations.

[4] Based upon 12 pollinations.

[5] Based upon 20 pollinations.

[6] Based upon 30 pollinations.

In the dehiscent-fruited species the seeds of section Hesperoyucca are flat, extremely thin and papery, smooth-surfaced, wingless, and irregularly ovate or oval in outline. With the exception of members of the *Yucca rupicola* alliance the seeds of section Chaenocarpa are similar to those of Hesperoyucca, but they possess a marginal wing that is exceptionally wide or conspicuous at the chalazal end of the seed. The seeds of *Y. rupicola* alliance are similar to those of other members of the Chaenocarpa, but their marginal wing is extremely narrow or wanting.

In general yucca seeds consist of hard, tough seed coats, an abundant horny endosperm, and a comparatively small embryo. The embryos of *Y. brevifolia* and the dehiscent-fruited species are straight, terete, and elongated, whereas those of the indehiscent-fruited species are somewhat shorter and more conical or subconical in shape. The cotyledonary leaf of the embryo is very large in proportion to the axis. The rudiment of the primary root is at the posterior end of the axis, and in the majority of species it is difficult to distinguish it from the cotyledon end. The plumule is undifferentiated or is distinguishable only by a dense meristematic region within the cotyledon at the anterior end of the axis.

Germination

The more or less waxy, tough, outer seed coat, the abundant endosperm, and the high vitality of yucca seeds result in their being well adapted to semiarid deserts. In germinating tests by the writer, the seeds were soaked in water for 24 hours, then placed between folds of moist cotton, and kept at temperatures between 28° and 32° C. Under these conditions germination was fairly uniform and was as follows:

Species	Germination (Days)	Species	Germination (Days)
Yucca brevifolia	3	*Yucca torreyi*	6
Y. whipplei	3	*Y. schidigera*	6
Y. elata	4	*Y. faxoniana*	7
Y. glauca	4	*Y. rupicola*	9

In the majority of tests, the germination periods were greatly reduced by carefully scarring or removing the seed coats at the hilum end of the seeds.

Out of approximately 75 germination tests, only 3 samples of seeds failed to show any germination. Two of these samples were from apparent hybrids between *Yucca glauca* and *Y. elata,* collected along the Rio Grande north of Socorro, N. Mex., and the other from a possible *Y. angustissima-Y. elata* hybrid, collected near Whiteriver, Ariz. The viability of the rest of the seed samples varied from 45 to 98 percent, with the majority ranging from 80 to 90 percent. Seeds of high viability were collected from fairly young, green fruits as well as from 2-year-old fruits, which were considerably weather-beaten. One lot of *Y. elata* seeds collected in 1942 showed approximately 95 percent germination in 1948.

In the semi-irrigated nursery at Riverside, Calif., the germination period of southwestern yucca seeds is spread over several years. When the seeds are planted in the early spring the first germination usually occurs within 1 or 2 weeks. This is followed by continuous germination of other seeds, until at the end of 2 or 3 years the plot is composed of seedlings varying from several months to several years old.

The first stage of yucca seed germination is the pushing out of the radicle at the base, or hilum end, of the seed. Apparently this appearance of the radicle is caused by simultaneous growth of the cotyledon and the radicle. At the end of 2 or 3 days the cotyledon has elongated to such an extent that the axis is well removed from the remains of the old seed. During this period, the primary root becomes well defined and the differentiation of the plumule within the cotyledon becomes more apparent. At the end of 4 days, the cotyledon has reached its maximum length; the plumule, still enveloped in the now swollen cotyledon, is well developed; and the primary root is considerably elongated and has root hairs. When the developing seedling is approximately 7 days old, the plumule breaks through the cotyledon (see pl. 62).

As a general rule, seed germination and seedling development of the capsular-fruited species is more rapid than that of the fleshy-fruited species. The length of cotyledon growth of the capsular-fruited species (see pl. 62) is much greater than that of the fleshy-fruited species (pl. 52). The longest cotyledon extensions measured for these groups were: *Y. elata* — capsular, 6.5 cm. long; and *Y. torreyi* — fleshy-fruited, 3.4 cm. long. In soil the cotyledon extension frequently forms an arch above the soil surface, thus removing the young seedling from the old seed remnants. As the seedling develops, it gradually becomes adjacent to the old seed and the cotyledon forms a protective sheath around the base of the plumule (pls. 52 and 62). In several cases the cotyledonary arch was broken soon after its formation, thus separating the young, undeveloped axis from the remains of the old seed. In all of these cases, the axis continued to develop and exhibited no adverse effects.

An early work *(1)* described the arch cotyledon as containing the complete embryo and concluded ". . . the embryo is thrown out previous to germination . . ." The formation of the cotyledonary arches in yucca and other monocotyledonous plants has caused some speculation as to growth reactions and tropisms involved. According to Trelease (*31*) the subterete elongated embryo obliquely placed across the seed and the arched cotyledon are characteristics of Yucceae.

Seedlings

Although southwestern yuccas produce an abundance of viable seed, reproduction by seed is very limited. During the writer's 4 years of field work he has recorded the following numbers of seedlings:

Species of more arid environs	*Seedlings*
Yucca elata	29
Y. baccata (southern N. Mex.)	9
Y. torreyi	8
Y. arizonica	7
Y. constricta	5
Y. reverchoni	3
Y. schidigera (Arizona)	1
Y. faxoniana	0
Y. carnerosana	0
Y. schottii	0
Y. rostrata	0
Y. thompsoniana	0

Species of less arid environs	*Seedlings*
Yucca glauca	72
Y. neomexicana	52
Y. rupicola	17
Y. baccata (northern N. Mex.)	16
Y. baileyi	13
Y. angustissima	6
Y. schidigera (southern Calif.)	6
Y. brevifolia	(1)
Y. whipplei	(1)

[1] Unlimited.

In a relatively dense stand of *Yucca elata* in southern New Mexico, Campbell and Keller *(8)* reported that in 17 annual chartings of 75 meter quadrats, only 10 seedlings were observed; and that in 1 year only 6 seedlings were recorded in 170 quadrats.

The paucity of yucca seedlings can undoubtedly be attributed to meager and irregular rainfall, to extremely slow growth and establishment of seedlings, and to rodent damage. The preceding list of species and seedlings are roughly placed into more or less arid groups. In the less arid group there are considerably more seedlings than in the more arid group. On the United States Jornada Experimental Range, near Las Cruces, N. Mex., where the mean annual rainfall is approximately 8.24 inches, the writer has recorded 7 *Y. elata* seedlings; whereas at the United States Department of Agriculture Field Station near Tucumcari, N. Mex., where the annual precipitation is approximately 16.42 inches, he found 46 *Y. glauca* seedlings. The viability and germination period of the seeds of *Y. elata* and *Y. glauca* collected at these localities are approximately equal. That the amount of rainfall is partly responsible for the lack of yucca seedlings is indicated by the distribution of *Y. brevifolia* seedlings in the Mojave Desert of California. In the lower valleys and mesas of this desert, the annual precipitation is meager and there are very few seedlings of *Y. brevifolia,* but in the higher mountain areas the rainfall is much greater and *Y. brevifolia* seedlings are plentiful. *Y. brevifolia* seedlings are particularly common in the vicinities of Yucca Valley and Twentynine Palms on the northern slopes of the Little San Bernardino Mountains.

It is very likely that yucca seeds often remain in the soil for several years and mainly germinate during the favorable seasons, which may be many years apart. On several occasions the writer has observed many seedlings of approximately the same age, but older or younger seedlings were lacking. In June 1945 approximately 20 seedlings of *Y. baileyi* var. *navajoa* were found in a relatively small area north of Tohatchi, N. Mex. Although these seedlings had only succulent, juvenile leaves, their subterranean growth indicated they were approximately 1½ to 2 years old. Five miles south of the area in another fairly dense concentration of variety *navajoa* no seedlings were found. Similar patches of seedlings of *Y. elata* have been observed near Silver City, N. Mex., and of *Y. gilbertiana* in the House Range of Utah. In these places the rainfall is sporadic.

Yucca seedlings are extremely slow in growth, and they retain their grasslike, often succulent, juvenile leaves for fully a year. Since the forage is scarce in the majority of the desert areas, such rodents as wood rats and rabbits habitually cut off the seedling leaves. Consequently, seedlings are often found that have characteristic shoots of 6- to 10-month-old plants, but their subterranean development indicates they are actually several years old.

In one of their meter quadrats, Campbell and Keller *(8)* charted a single *Y. elata* seedling for 6 years, when it disappeared. After 3 years had elapsed, the seedling reappeared and continued to grow. The authors attributed the plant's disappearance to rodent damage. In many of the drier parts of the southwestern deserts, grazing by sheep and goats is particularly damaging to yucca seedlings. In areas of higher rainfall and, consequently better forage conditions, yucca seedlings develop normally and rarely exhibit evidence of rodent damage.

Aerial Characters

The juvenile leaves of yucca seedlings are commonly succulent, flaccid, and usually a glaucous blue green. The seedlings of capsular-fruited species and of *Yucca brevifolia* have numerous, usually narrow, and markedly grass-like leaves (pls. 53 and 62), whereas the seedlings of the fleshy-fruited species have comparatively few, generally broad, rather reedlike leaves (pl. 52).

When the seedlings become 4 to 6 months old the juvenile leaves are gradually replaced by small maturelike leaves, which in turn are gradually replaced by typically matured leaves (pls. 52 and 62). This transformation requires from 18 months to 3 years.

Following the formation of matured leaves, some of the species are distinguishable in their seedling stage, but others are difficult or impossible to separate. The seedlings that are rather easily separated and the characters distinguishing them are:

Yucca faxoniana, with leaves comparatively short, broad, deeply concave, dark green, and short, coarse, curly marginal fibers.

Y. schottii, with leaves thin, slightly concave, light glaucous green, and without marginal fibers (pl. 52).

Y. arizonica, with leaves narrow and a few fine, straight marginal fibers (pl. 54, *B*).

Y. baccata-Y. arizonica (*Y. thornberi* McKelvey) (Superior, Ariz.), similar to *Y. torreyi* and *Y. baccata* but with leaves more glaucous blue green and somewhat longer, less curled marginal fibers.

Y. torreyi (from west-central Texas), with leaves long, broad, light green and rather long, fine, slightly curled marginal fibers.

Y. brevifolia, with head of numerous ascending leaves; leaves short, narrow, stiff, blue green, and serrate margins.

Y. brevifolia var. *jaegeriana,* with head of numerous spreading leaves; leaves very short, narrow, stiff, yellowish green, and serrate margins.

Y. whipplei, with leaves long, narrow, rather flaccid, drooping, dark blue green, with serrate margins.

Y. whipplei var. *parshii* ?, with leaves long, broad, stiff, spreading, wavy, glaucous blue green, with serrate margins.

Y. whipplei var. *caespitosa,* with numerous auxiliary leaf heads, leaves similar to those of species.

Y. thompsoniana, with head of numerous leaves; leaves rather long and narrow, stiff, spreading, yellowish green, with horny, yellow, serrate margins.

Y. reverchoni, with head of few leaves; leaves short, narrow, stiff, spreading, yellowish green, with horny, yellow serrate margins.

Y. rupicola, with head of very few leaves; leaves long, broad, rather flaccid, twisted, wavy, with horny, yellow margins and brown serrations.

Y. neomexicana, with leaves narrow, straight, spreading, with few fine straight fibers.

Y. gilbertiana, with leaves broad, wavy, somewhat falcate, with numerous coarse, curly fibers.

Y. baileyi var. *navajoa* (Tohatchi, N. Mex.), similar to *Y. glauca, Y. baileyi, Y. constricta,* and *Y. elata,* but with leaves shorter and more filiferous.

Y. elata (Vail Junction, Ariz., State College and White Sands National Monument, N. Mex.), similar to *Y. glauca, Y. baileyi,* and *Y. constricta,* but with considerably more leaves than equally as old seedlings of the other species.

All of the above seedlings comprise fairly uniform populations. Single plant progenies composed of two or more types of seedlings are:

Y. torreyi (State College, N. Mex., and El Paso, Tex.), with leaves either (1) large, straight, spreading; or (2) small, skewed-falcate.

Y. torreyi (Sonora and Sterling City, Tex.), with leaves either (1) large, straight, spreading, rather light green; or (2) a typical blue form (p. 23); or (3) an intermediate type.

Y. baccata (Mountain Park, N. Mex.) either (1) vigorous, with leaves straight, spreading, rather light green, and quite coarse, curly marginal fibers; or (2) very small, with leaves skewed-falcate, dark green, and very coarse, curly marginal fibers; or (3) an intermediate type.

Y. whipplei hybrid? (Cajon Pass, San Bernardino County, Calif.), either (1) solitary, with leaves long, narrow, stiff, straight, spreading, and very glaucous blue green; or (2) caespitose, with leaves long, wide, falcate, somewhat flaccid, spreading, and very light, glaucous blue green; or (3) an intermediate type (pl. 55). When these seedlings were 15 months old they segregated as follows: 20 seedlings solitary with broad, very glaucous, light blue-green leaves, and 2 seedlings, caespitose, with 8 and 14 secondary leaf heads, derived from buds in axes of seedling leaves; leaves rather narrow, stiff, straight, slightly glaucous, dark blue green.

Single plant progenies with types distinguishable only or mainly by reproductive characters are:

Y. thompsoniana-Y. reverchoni? (Sheffield, Tex.), seedlings either (1) *Y. thompsoniana* type with numerous long leaves, long flowering stalk, and large, broad panicle; or (2) *Y. reverchoni* type, with few short leaves, short flowering stalk, and small, narrow panicle; or (3) a quite variable intermediate type.

Y. glauca hybrid? No. 11 (Tucumcari, N. Mex.), seedlings with either (1) panicle narrow with dorsal side of branchlets forming a narrow angle with inflorescence stalk, pistil roughly glandular, style tumid with basal lobes protruding over ovary, capsules very rough and glandular, anther depressions large and deep; or (2) panicle broad with dorsal side of branchlets forming a wide angle with inflorescence stalk, pistil smooth, style slender, not lobed, capsules smooth, no glands or anther depressions.

Y. glauca hybrid? (*Y. intermedia* McKelvey) (Grant, N. Mex.), inflorescences either (1) strictly racemose (pl. 42); or (2) slightly branched; or (3) one plant, very likely owing to teratological variation, broadly paniculate. The inflorescence bud of this plant developed very slowly and produced very short, broad leaves that terminated in a large, pungent, incurved hook. When the foliaceous inflorescence was 11 months old (82 cm. long) the bud became more active and rapidly developed a normal, broad, ellipsoidal panicle that produced normal flowers, capsules, and seeds (pl. 43).

Y. constricta-Y. elata? (*Y. campestris* McKelvey) (Big Springs, Tex.), seedlings with either (1) scape short, stout, panicle extending into foliage, narrowly ellipsoidal, branchlets very ascending, flower green, style stout, swollen at base, and protruding over ovary; or (2) scape long, weak, panicle well above foliage, broadly ellipsoidal, branchlets barely ascending, flower white or greenish white, tinged with purple, style slender, not protruding over ovary.

Progenies of field selected for definite characters are:

Y. schottii (Patagonia, Ariz.), (1) all seedlings of selected longleaf plant had long leaves (average 71.7 cm.); (2) all seedlings of shortleaf plant had short leaves (average 50.7 cm.).

Y. glauca hybrid? (Tucumcari, N. Mex.), field plant selected for long leaf and large, broad panicle; all seedlings had long leaves, but segregated into two types of panicles (see *Y. glauca* hybrid No. 11 above).

Y. elata (Vail Junction, Ariz.), field plant selected for long, drooping or skewed-falcate leaves, one seedling had leaves similar to parent, and five seedlings had comparatively narrow, short leaves.

Y. elata (White Sands National Monument, N. Mex.), all seedlings from selected longleaf plant had long leaves (average 101.5 cm.).

Y. elata (State College, N. Mex.), all seedlings from selected shortleaf plant had short leaves (average 49.0 cm.).

Only one lot of seedlings of *Y. schidigera* (Twentynine Palms, Calif.) has been grown. These seedlings had rather short, skewed-falcate, dark glaucous blue-green leaves. They were very similar to the skewed-falcate-leaved plants of *Y. torreyi* from State College, N. Mex., and El Paso, Tex., and of *Y. baccata* from Mountain Park, N. Mex.

It is very likely that the skewed-falcate-leaved plants of *Y. baccata* constitute an undescribed type, differing from the species and its variety *vespertina* in its small clump of few leaf heads, and its very short, skewed-falcate dark-green stiff leaves. The writer has noted such plants thinly scattered on the rolling, dry grassland hills in west-central New Mexico.

In the seedlings listed above, the major genetical variations occur either (1) as a progeny of uniform seedlings, all differing from the seed parent; or (2) as a progeny of several types of individuals. In the first group are the uniform straight, spreading-leaved progeny and the uniform small, skewed-falcate-leaved progeny from typical *Y. torreyi* occurring at State College, N. Mex., and El Paso, Tex. Possibly belonging to the same group are the typical, blue-green, and intermediate progenies from typical *Y. torreyi* occurring at Sonora and Sterling City, Tex. It is very likely that these variations are a result of hybridization, since the straight-leaved seedlings are indistinguishable from *Y. torreyi* seedlings and the skewed-falcate-leaved seedlings resemble similar seedlings of *Y. baccata.* In the second group, or progeny of several distinct types of individuals, are the seedlings of *Y. whipplei* from Cajon Pass; *Y. baccata* from Mountain Park; *Y. thompsoniana* from Sheffield; *Y. glauca* from Tucumcari and Grant; and *Y. constricta* from Big Springs. It has been shown that the *Y. whipplei* seed parent was probably an intraspecific hybrid between varieties *parishii* and *caespitosa,* and that the seedlings segregated into the two varieties, as well as the hybrid form. The seedlings of *Y. baccata* probably also represent an intraspecific hybrid segregation, since they are of three types, a typical *Y. baccata,* a small skewed-falcate-leaved form, and an intermediate form. The *Y. thompsoniana* seedlings were from a plant noted to be a possible hybrid with *Y. reverchoni.* The progeny segregated into forms resembling *Y. thompsoniana, Y. reverchoni,* and a form midway between these species. *Y. glauca* apparent hybrid from Grant segregates into a racemiform type and a paniculate type. *Y. glauca* from Tucumcari and *Y. constricta* apparent hybrids segregate into distinct inflorescence and flower types.

Although many of the variations that occur in native yucca fields are undoubtedly caused by environmental conditions, such progenies as the short-leaf and longleaf selections of *Y. schottii* show that variations are frequently caused by minor genetical differences. These differences undoubtedly account for the variations in leaf size and habit of the various progenies of *Y. torreyi, Y. elata,* and *Y. glauca.*

Subterranean Characters

The primary roots of young yucca seedlings are characteristic of monocotyledonous seedlings. When they are from 10 to 18 cm. long, they are succeeded by lateral roots (pls. 52, 53, and 62) that develop from the axis. These roots soon become very swollen and more or less fusiform in shape. They are covered with a smooth, yellowish- or reddish-brown epidermis and have a typical protostele root structure. The stele and endodermis are very small in comparison with the thick layers of cortical parenchyma cells. The latter tissue is very succulent, and upon slight pressure it readily collapses and separates from the relatively hard endodermis and stele.

At the preceding stage of development, or when the seedlings are approximately 3 to 5 months old, only one species is distinguishable by its subterranean growth. This species, *Yucca whipplei,* forms a definite, swollen, bulb-

like, undergrowth stem; whereas in all other species this bulbous appearance is very slight or wanting (pl. 53).

All species continue to form secondary roots until the seedlings are approximately 6 to 8 months old, when, with one or two exceptions, the dehiscent-fruited forms follow a rhizomatous development (pls. 62 to 72), whereas the indehiscent-fruited species form a typical fibrous root system (pls. 52 to 61).

Four-year-old seedlings of all indehiscent-fruited species have a well-developed fibrous root system. These roots spring from the rounded, somewhat swollen base of the seedlings and spread obliquely into the soil. At approximately this stage of development, the seedlings of *Y. arizonica* and *Y. baccata* (pl. 54) form from 1 to 4 fairly large nodules just below the soil surface in the region of the young seedling axis. These nodules extend from 6 to 10 cm. from the seedling, and are covered with a thin, rough bark. On their undersurface, succulent fusiform roots develop, and at the tip of each, a large leaf-head bud is produced. In only one other indehiscent-fruited species has such leaf-head formation been observed in the seedling stage. In this case, 7 out of 10 *Y. torreyi* seedlings, from seed collected in the vicinity of State College, N. Mex., produced a single head of leaves from a rhizomelike nodule.

Five- to eight-month-old seedlings of the capsular-fruited yuccas exhibit a single, relatively short primary root and from one to four long, succulent, fusiform, secondary roots. The primary root is seldom branched, but the secondary roots usually have from one to three branches toward their ends. Both types of roots are covered with a smooth, thin, reddish- or yellowish-brown epidermis and have a protostele structure. Except for *Y. whipplei,* when the seedlings are between 6 and 9 months old, a large swelling occurs on the axis and soon develops into a scale-covered rhizome bud (pl. 62). Although only one bud usually forms, occasionally two or three are concurrently developed. The rhizome develops very slowly and is covered with a thick, smooth epidermis. It has a dictyostele structure, lacks leaf scales, and terminates in a large blunt, scale-covered bud. From the rhizomes, fine, branched roots and large fusiform adventitious roots develop. The latter rhizome roots are indistinguishable from the secondary axis roots, which they soon replace. They have a protostele structure. In all species, except *Y. elata,* the rhizomes soon branch (pl. 63) and mainly develop obliquely into the soil. In *Y. elata* seedlings, the rhizome remains unbranched and grows vertically downward (pl. 64).

Three- to four-year-old seedlings of *Y. whipplei* and its varieties *parishii* (*?*) and *caespitosa* do not form rhizomes. Equally as old seedlings of apparent hybrids between the latter varieties appear to have short rhizomes, which ascend obliquely from the seedling axis region and terminate in a single leaf head. The writer has not grown seedlings of *Y. whipplei* var. *percursa,* and he has examined only very young seedlings of *Y. rostrata, Y. thompsoniana,* and *Y. angustissima.*

In the preceding taxonomic section, it was shown that many of the transitional forms of *Y. glauca* varied considerably in the number of leaf heads per square meter, and, in general, the plants of western New Mexico were less dense than those of eastern New Mexico. Such density undoubtedly is partly caused by either a combination of the frequency of rhizome branching, the length of rhizome branches, or the frequency of rhizome leaf-head formation. That a possible correlation exists between the amount of rhizome

branching and plant density is indicated by the following differences in rhizome behaviors:

Yucca glauca hybrid? (Tucumcari, N. Mex.). — Seed parent density, 11.2 heads of leaves per square meter; 71.43 percent of the rhizomes of 15-month-old seedlings had from 3 to 5 branches.

Yucca glauca hybrid? (Grant, N. Mex.).— Seed parent density, 5.5 heads of leaves per square meter; 50.02 percent of the rhizomes of 15-month-old seedlings had from 2 to 4 branches. The rhizomes in these seedlings were approximately the same length.

ROOT AND SHOOT CHARACTERS OF MATURE YUCCAS

Indehiscent-Fruited Species

In matured field plants the base of the trunklike stem is either flat (in *Yucca carnerosana, Y. faxoniana,* and *Y. brevifolia,* and rarely in *Y. schottii, Y. torreyi,* and *Y. schidigera*) (pls. 56 and 57), or rounded (in *Y. arizonica* and *Y. baccata,* and commonly in *Y. schottii, Y. torreyi,* and *Y. schidigera*) (pl. 58). Except in *Y. brevifolia,* the margins of the flat bases are wavy in outline and rounded under, giving a folded appearance. These rounded margins extend several centimeters into the soil and they appear to be composed of highly active tissue. Just inside of the rounded margin, a band of fibrous roots encircles the stem base (pl. 56). The rounded or hemispherical stem bases extend 20 to 40 or more centimeters into the soil. Although the roots of these plants are mainly limited to the outer regions of the rounded base, they do not occur in a definite band. The roots of all plants are long and tough. In typical flat-based species, the roots are less branched and slightly larger in diameter than those of the species with rounded bases.

In *Y. carnerosana, Y. faxoniana, Y. schottii, Y. torreyi,* and *Y. schidigera* basal sprouts develop from nodules formed in the active tissues at the base of the stem (pl. 57). These nodules are formed just below the soil surface and are usually hemispherical in shape. They are covered with a rather thick, rough bark. A few fibrous roots develop in the under surface of the nodules, and on their upper surface, usually toward the center, a sprout bud is formed.

The nodules are always close to the soil surface, and, except in *Y. torreyi* and *Y. schidigera,* no subterranean stem extensions other than the nodules themselves have been observed. The nodules of *Y. torreyi* and *Y. schidigera* occasionally extend 15 to 20 cm. from the parent stem (pl. 58). In no case, however, have these extensions been found to have terminal buds, and sprout formation from them appears to be entirely adventitious.

Yucca carnerosana, Y. faxoniana, and *Y. schottii* commonly have 1 or 2 and rarely up to 5 basal sprouts. All sprouts are produced at the base of the stems and are contiguous to the mother stems. Plants having 2 or 3 equally tall stems are believed to have developed either from sprouts of an old stem that no longer exists or from multiple-stemmed seedlings. *Y. torreyi* and *Y. schidigera* commonly have 1 to 5, and rarely up to 10 or more sprouts, which are adjacent, or close to the mother stems.

Slightly north of Stoddard Well, in May 1943, the writer found a large burned grassland area, containing numerous plants of *Y. schidigera.* It

seemed probable that the fire had occurred the previous summer. Upon examination of the *Y. schidigera* plants, only a comparatively few were found to show any signs of life and it was concluded that practically all plants had been killed by the fire. In May 1944 the plants were again examined and it was found that although all of the old shoots had been killed to, or nearly to, the ground, practically all plants had formed one to four sprouts at the bases of the old burned stems. Although a few plants showed no signs of recovery, it was estimated that, owing to an increase in sprout production, the stand would eventually be as dense or somewhat denser than before the fire. However, the sprouts were all small and growth rates indicate that full leaf-head-size recovery would take at least 5 years longer and that many years would pass before the sprout stems were as tall as the old burned ones. Similar recovery of burned plants has been observed in *Y. carnerosana* and *Y. rostrata.*

In *Y. arizonica* and *Y. baccata* the nodules commonly produce a terminal bud from which a rhizomatous extension or a stem develops (pl. 54). Although these stems are usually symmetrical and broadly conoid in shape, they are occasionally quite irregular. In *Y. arizonica,* such rhizomes are from 8 to 15 cm. in diameter and 15 to 30 cm. long, while in *Y. baccata* they are approximately the same diameter but from 20 to 55 cm. long. The rhizomes are covered with a thick, checked bark and have typical dictyostele structure. They terminate in a very blunt bud that is covered with closely imbricated, large brittle scales. One or two adventitious sprouts develop along the rhizome's upper surface, and adventitious roots are produced along its undersurface. The roots are of a protostele structure.

In *Y. baccata* the rhizomatous stems are apparently long-lived, and in many plants their continuous production and occasional branching forms a confused netlike system just beneath the soil surface.

Benson and Darrow *(3, p. 71)* described *Y. baccata* as, "Stems 1 – several, subterranean or lying on the ground; leaf-rosettes clustered or solitary at ground level . . ." From this description it is not clear whether aerial procumbent stems are of rhizomatous or of aerial origin. Since the stems of the two types of origin are quite distinct and result in different types of clumping, it is an important character in separating typical *Y. baccata* from its transitional forms. Rhizomatous, or basal sprout, stems never elongate after their terminal bud forms a leaf head. Although such stems are usually subterranean and horizonal, they are rather commonly aerial, or partially aerial, and may be ascending. In *Y. baccata,* such rhizomatous stems are easily distinguishable in that they are always short and thick, lack leaf bases or leaf scars, and are irregular in shape following leaf-head formation (pl. 59). Procumbent stems of aerial origin are those stems that are produced by the growth and elongation of the leaf-head bud and stem. They are thus formed after the leaf head and are always aerial. Such stems, at least in *Y. baccata,* usually exhibit leaf remnants or leaf scars; are generally long, slender, and uniform in shape; and terminate in an erect head of leaves. In plate 59 the lower stem was only partly buried in the soil and the upper stem was entirely aerial. The lower stem is rhizomatous, and as it terminates in a leaf head the rhizomatous part of the stem has completed its growth. The basal half of the upper stem is rhizomatous, whereas the top half is a typical assurgent-erect stem.

Owing to the fact that rhizomatous stems are short and frequently from adventitious shoots, plants that are limited, or practically limited, to such stems

are usually dense. Procumbent stems of leaf-head origin usually spread out from plant centers and result in a rather large open clump or large clumps with fairly open centers and dense marginal bands of upturned heads of leaves. In many cases the latter clumps become rather confusing by the formation of additional rhizomatous sprouts. Procumbent-stemmed plants of transitional forms of *Y. baccata-Y. arizonica* are rather common south of Vail, Ariz., and *Y. baccata* plants exhibiting aerial rhizomatous stems are rather abundant along the highway east from Cornudas, Hudspeth County, to El Paso County, Tex.

In this group of plants, adventitious root production from aerial stems appears to be quite variable and may depend upon environmental conditions. In the vicinity of Valley Wells and Kessler Springs, Mojave Desert, Calif., many plants of *Y. baccata* variety *vespertina* and apparent hybrids between this variety and *Y. schidigera* were found, with aerial stems that lie on the ground. In several of these cases, the apical ends of the stems turn upward and extend fully a meter high. Where these stems come in contact with the soil, scattered roots occur. Occasionally the older, or lower, end of the stem has decayed completely through and roots are plentiful just below the upturned apical end. Similiar plants of apparent *Y. baccata-Y. arizonica* hybrids occur south of Vail, Ariz. Many procumbent stems of these plants were examined and only occasionally were they rooted.

In *Y. brevifolia,* the stem base remains bulb-shaped until the plants are between 2.4 to 4.0 m. tall, when from four to eight large rounded extensions, or protrusions, develop just above the roots. These protrusions are 5 to 8 cm. in diameter, 8 to 12 cm. long, and they are covered with a thick, relatively smooth whitish-gray bark. They extend obliquely downward and appear to be composed of comparatively active tissues. Except in forma *herbertii* the bases of old *Y. brevifolia* plants are elephant-foot-like and set flat on the ground. In these plants the protrusions are broad, fairly long, and flattened on their under side. They radiate from the center and are mainly dichotomously lobed (pl. 60). The roots are long, tough, and cordlike, and they are mainly limited to a marginal band immediately below the protrusion lobes.

In several *Y. brevifolia* concentrations, approximately 5 percent of the plants produce basal sprouts. These sprouts are formed from nodules that develop slightly above the soil surface on the bases of the older stems. No nodules or sprouts have been found to produce roots, and only limited evidence indicating that the sprouts grow to an appreciable size has been obtained.

Yucca brevifolia and its variety *jaegeriana* are mainly single-stemmed, but occasionally they have two or three stems and very rarely form a clump of several stems. Forma *herbertii* is a typical clumped plant. The clumps of *herbertii* are usually very large and so dense that they are impenetrable. Upon the excavation of parts of several clumps, it was found that all aerial stems were apparently attached to each other by rhizomatous stems and that the area and density of the clumps were still increasing.

The rhizomatous stems appear to originate shortly following protrusion formation, from buds intermingled with, or occasionally above, the protrusion (pl. 61). These buds are small in diameter (10 to 15 mm.), elongated (15 to 20 mm.), and sharply pointed. They are closely imbricated by large, triangular (altitude 12 mm.), brittle, brown scales. The rhizomes are horizontal or obliquely-ascending and range from 0.2 to 1.3 m. long and from 1 to 3 cm. in diameter. When first produced, the rhizomes are unbranched,

rather succulent, and covered with a thin, brown epidermis. The nodes are well marked by leaf scales, which are retained on the full length of the young rhizome. From the nodes unbranched, succulent roots develop. The rhizomes have a typical monocotyledonous dictyostele structure, whereas the roots exhibit a protostele structure. Apparently the young rhizomes develop rapidly and soon ascend to the soil surface, where they produce a head of leaves.

Following sprout formation the young rhizomes lose their succulence and become woody and tough. During this transformation, the thin epidermis and bud scales are replaced by a thick, checked, dark-brown bark. Occasionally old rhizomes branch, and the branches produce sprouts close to the mother stems.

In the plant shown in plate 61, the mother stem was approximately 2.0 m. tall. At the base of the stem are 8 protrusions, 10 rhizome buds, and 8 rhizomes, which vary in length from 0.1 to 1.2 m. Of the 8 rhizomes, 6 have a thin epidermis and leaf scales at the nodes. The remaining 2 are covered with a thick, rough bark, and each is once-branched.

Whether the formation of rhizomes in *Y. brevifolia* and variety *jaegeriana* is a normal behavior or a result of stem injury is uncertain. In the centers of several clumps of these forms a single decayed stem has been found. This evidence, in conjunction with the known sprout production following stem injury in other species, indicates that rhizomatous stem development in *Y. brevifolia* and its variety is in some way stimulated by shoot injury. Rhizomatous stem development in this group may also depend upon the amount of precipitation. It has been noted that in the lower, drier parts *Y. brevifolia* rarely forms more than one or two stems, but in the higher, moister areas two- and three-stemmed plants are quite common and occasionally small clumped plants are found. The annual precipitation in the type locality of forma *herbertii* is between 14 and 16 inches.

Dehiscent-Fruited Species

Yucca rostrata, Y. thompsoniana, and *Y. whipplei* and its varieties *parishii* (?) and *caespitosa* are the only capsular-fruited southwestern yuccas that do not, or rarely, form rhizomes.

The leaf-head bases of *Y. whipplei* and variety *parishii*(?) are cup-shaped and extend 10 to 25 cm. into the soil. Except for a relatively small area in the center, these bases are covered with closely imbricated leaf bases. From the base centers, many sparsely branched roots extend into the soil. The plants never produce rhizomes or sprouts.

The leaf-head base and roots of 1-year-old seedlings of variety *caespitosa* are indistinguishable from those of the species or variety *parishii* (?). However, when the seedlings of variety *caespitosa* are from 14 to 20 months old they develop from 4 to 16 buds in the axils of the outer leaves. Soon after the formation of these buds, the leaf-head base enlarges and somewhat flattens. This enlargement is followed by the production of succulent, fusiform roots that are similar to the roots of 5-month-old seedlings. The axillary leaf heads of many 20-month-old seedlings are very similar to younger mother leaf heads. However, they are somewhat flattened and their leaves are narrower than either those of the mother leaf head or of younger seedlings.

Old field plants of variety *caespitosa* have a very small, thick, irregularly shaped, or lobed, caudex. This caudex is approximately 7 to 15 cm. long, 5 to 9 cm. in diameter, and extends 5 to 10 cm. above the soil surface. The base of the caudex is extremely broad and bowl-shaped and extends very slightly into the soil. From the very bottom of the base, in an area hardly larger than that occupied by 20-month-old seedlings, long cordlike roots spread into the soil. The aerial part is composed of numerous axillary rosettes attached to the caudex. The production of axillary leaf heads is apparently repeated over and over until the resultant cluster is a very confused tangle of crowded rosettes that completely covers the small caudex.

In the apparent *Y. whipplei*-*Y. whipplei* var. *caespitosa* hybrids the rhizomes are initiated at the base of the stem, contiguous to the roots, in the form of small, elongated buds. Matured rhizomes are 2 to 4 cm. in diameter, 40 to 95 cm. long, and covered with a comparatively thick bark. They produce adventitious roots and terminate in a bud, which ultimately forms a sprout. In several plants these rhizome sprouts have been found to produce axillary leaf heads. They are usually very close to the mother cluster, and unless the plant is carefully examined the original mother cluster and the rhizome-developed cluster cannot be separated. From one to eight rhizomes have been found around the base of a single mother cluster of such apparent hybrids.

Although the writer's studies of the subterranean system of *Y. whipplei* var. *percursa* have been limited, these studies, in conjunction with those of the aerial habit, indicate that sprout formation is mainly a result of rhizomatous development.

The subterranean development of 2-year-old seedlings of *Y. thompsoniana* is similar to that of the majority of indehiscent-fruited species. They show no indication of rhizome development. However, young field plants, estimated to be 5 to 7 years old, exhibit a slightly swollen (2.5 to 4.0 cm.) leaf-covered base, from which a short, thick, rhizomatous stem extends straight downward for 12 to 20 cm. (see pl. 68,*A*). This rhizomatous stem at the union with the aerial stem is 1.5 to 3.0 cm. in diameter, and it gradually increases toward the base to 3.5 to 6.5 cm. in diameter. At the latter point, it rapidly flares out to an irregularly shaped mass that is approximately 10 to 18 cm. in diameter and more or less flat on the bottom. From this swollen base, and rarely from the stemlike portion, numerous, elongated fusiform, succulent roots spread into the soil. The rhizome is covered with a comparatively rough, thick bark, whereas the roots are covered with a smooth, thin, dark-red epidermis.

In older plants of *Y. thompsoniana* the massive rhizomatous base is very similar to the rounded base of *Y. torreyi*. It is from 20 to 30 cm. below the soil surface and is about 40 to 60 cm. in diameter (pl. 69). It is extremely irregular in shape and exhibits many lobes and protrusions. The roots are long, thick, tough, and cordlike. Sprouts are rarely produced unless the old shoot is injured.

In the preceding section it is shown that all other southwestern capsular-fruited yuccas form definite rhizomes (pls. 62 to 72). These rhizomes develop from buds formed on the axis, when the seedlings are between 5 and 9 months old. In mature plants the rhizomes are of two types: Horizontal or somewhat oblique and vertical.

Yucca rupicola, *Y. reverchoni, Y. neomexicana, Y. gilbertiana, Y. glauca, Y. baileyi, Y. angustissima,* and *Y. constricta* are characterized by oblique or

horizontal rhizomes (pls. 63, 66, and 67) that in the majority of cases follow a definite pattern of development. Shortly after the seedling rhizome is produced, it gradually branches and rebranches (pl. 63). These branches spread out more or less horizontally in all directions. Following the development of these branches, or when the seedling is approximately 4 to 6 years old, short vertical branches, or risers, are formed along the upper surface of the older rhizomes. Upon reaching the soil surface, each riser produces a head of leaves. Following leaf-head formation, the upper part of the rhizome, immediately below the young sprout, gradually increases in diameter and becomes very active. It soon produces several lateral rhizomes that branch freely. At the latter stage, the young shoot and its rhizome are similar to those of 4- to 6-year-old seedlings. Soon after sprout formation, the old rhizome uniting the shoot with the mother plant appears to become less active (pl. 67). Although the connections usually remain alive in a dormant condition, occasionally they die and soon decay.

The rhizome system of large plants is a very confused network that generally lies from 10 to 60 cm. below the soil surface (pl. 66). Mature rhizomes are covered with a thick, rough bark. They lack nodes and leaf scales and terminate in blunt, scale-covered buds. Although the roots mainly occur immediately below the sprouts on the risers, they are also thinly scattered along the entire length of the horizontal rhizomes.

The rhizomes of the various species differ considerably in size and number of sprouts they produce. Of the largest rhizomes found in several species, the range in length was from 15 to 30 cm. in *Y. reverchoni* to 75 to 300 cm. in a transitional form of *Y. glauca;* diameters ranged from 1.5 to 2.0 cm. in *Y. reverchoni* to 6.0 to 10.0 cm. in *Y. baileyi.*

The dense, small clump habit of *Y. reverchoni* is mainly the result of rhizome-sprout production. Since the rhizomes are very short and highly branched (pl. 68,*B*), it is difficult to determine if the sprouts originate from risers or from the terminal buds of horizontal rhizomes. In several young plants, however, upturned buds of horizontal rhizomes strongly indicate that rhizome branches ultimately terminate in a leaf head. In this species, adventitious or axillary aerial leaf-head formation plays a secondary part in clump development.

Although *Y. gilbertiana* is mainly a dense, compact clump, it is occasionally a rather open clump, with small scattered heads of leaves. In the former cases, the rhizomes are large in diameter, comparatively short, thinly branched, and lie obliquely in the soil. In such plants leaf-head production is mainly of aerial formation and rhizome-produced sprouts add very little to the density of the plants. Although plants of *Y. gilbertiana* exhibiting scattered heads of leaves have not been examined, they are undoubtedly of rhizomatous origin.

The dense nature of *Y. glauca* and *Y. baileyi* is mainly the result of aerial leaf-head production. In these plants, as well as in *Y. baileyi* var. *navajoa,* there are usually one or two main rhizomes that are large in diameter, comparatively short, and oblique. Rhizomatous sprouts are produced from short risers and from terminal buds of horizontal branches that develop around the upper parts of the main rhizomes.

In *Y. rupicola, Y. neomexicana, Y. angustissima,* and many transitional forms of *Y. glauca* the heads of leaves are rather thinly scattered. In these plants secondary leaf heads are mainly of rhizomatous origin. The rhizomes

are relatively thin in diameter and very long (pl. 67). They are mainly horizontal and, although much-branched, the branches are comparatively far apart. Although the sprouts are mainly produced from risers, they are occasionally formed at the ascending ends of long horizontal rhizomes.

Large plants of *Y. glauca* are extremely difficult to destroy. In cleared and cultivated fields, regardless of deep seasonal plowing, it will continue to sprout for three or more years. Many plants that have been entirely deprived of shoots by fire or cutting put forth within a year or two as many or more shoots than they originally possessed. All of these sprouts or shoots develop from the netlike rhizome.

Yucca elata is characterized by one or more large vertical rhizomes, which produce short risers. The formation of the rhizome system is very similar to that previously described in species exhibiting horizontal or oblique rhizomes. In *Y. elata,* however, the seedling rhizome continues to develop slowly downward throughout the plant's life (pls. 64, 65, and 70) or until it is replaced by another vertical rhizome of shoot origin. When the seedling is approximately 5 to 6 years old, the large vertical rhizome usually produces one or more branches. These branches are always formed around the upper end of the rhizome or from 8 to 30 cm. below the soil surface. They are short and ascending and apparently always form secondary heads of leaves that are adjacent to, or very close to, the mother seedling. During the development of the secondary leaf heads, the short, ascending rhizome from which it was derived increases in diameter and occasionally produces lateral buds. Apparently these buds either ascend to the surface and form additional leaf heads or, rarely, turn downward and produce a second larger vertical rhizome.

The external morphology and root distribution of the rhizomes of *Y. elata* are similar to the descriptions previously given for species exhibiting horizontal rhizomes. The vertical rhizomes of mature plants are commonly 1.0 to 1.5 m. long and occasionally up to 2.0 m. Although they usually vary between 8 to 15 cm. in diameter, several plants with rhizome diameters ranging between 15 and 28 cm. have been excavated. The lateral or ascending branches vary from 15 to 20 cm. long and from 2.5 to 8.0 cm. in diameter.

Yucca elata usually forms a rather tall, open clump that occupies a comparatively small area. The clump is usually composed of one to five aerial, trunklike stems, with a few scattered shoots around their bases. Outside of the possibility of seedlings with twin shoots, all of the stems and shoots, except the seedling stem, are of rhizomatous origin. Aerial stem branching and leaf-head production add very little to the clump. Occasionally in sand dune areas the clumps are somewhat denser, larger in area, and shorter in height. Partial excavation of several of the latter plants indicated that their larger area and denser habit were undoubtedly caused by a higher frequency of vertical rhizome branching. The shorter height is probably an adaptation to windstorms and sandstorms.

Both rhizomes and trunklike stems of *Y. elata* freely produce adventitious heads of leaves. Many plants with old leaf heads that had been completely destroyed by fire have been examined. In the less severely burned plants, the new leaf heads are formed in approximately equal numbers along the sides of the old aerial stems and from the rhizomes adjacent to the stems. All sprouts of severely burned plants are of rhizomatous origin and are close to the old burned stems. Occasionally along washes and ravines, the large vertical rhizomes of *Y. elata* are exposed. In these plants it is not uncommon to

find the rhizomes replacing the aerial stems. Along the sides of the rhizomes, adventitious leaf heads are produced and the old leaf heads and aerial stems, as if too high, die and slough off.

Many fallen or bent trunklike stems of *Y. elata* that were partially covered with soil and retained their original roots have been examined. The apical ends of these stems frequently grow upward for a meter or more. However, none of these stems have been found to produce either roots or heads of leaves along their sides.

Undoubtedly one of the most interesting growth habits of southwestern yuccas is that of *Y. elata* in White Sands National Monument, N. Mex. The plants establish themselves in open spaces, between the dunes, and as the dunes move into these spaces, the plants gradually become covered. The stems of plants toward the edges of the rising dunes grow at a sufficient rate to keep their heads of leaves above, or nearly above, the dune surfaces, and the plants toward dune centers are completely covered. Consequently, toward the dune crests, the stems appear to become shorter and shorter until only the heads of leaves remain above the sand. Occasionally along the higher dune fringes only the flowering stalks or fruit stalks appear above the sand.

As the dunes drift onward and the trunklike stems of *Y. elata* are gradually uncovered, numerous adventitious roots are revealed (pl. 71). These cordlike roots frequently extend 7 m. or more over the white sand. Although the old stems are mainly covered with a rough bark, occasional scattered bands of leaf remnants completely encircle them. Now and then rhizome risers are found adjacent to the trunklike stems. These risers are long and thin, and toward their ends the nodes are well marked by scales (pl. 72). They always appear to be of deep subterranean origin, and they are probably branches of the seedling rhizome. When the dunes have receded 2 or 3 m., the stems produce adventitious leaf heads toward their bases and the upper part of the old stem, as if it can no longer obtain nutriment or support itself, bends over and finally dies and sloughs off (pl. 72). Occasionally the ends of bent-over stems have the appearance of having been broken previously. These broken ends, in conjunction with parts of decayed stems close by, indicate that the height-adjustment process has probably occurred several times during the stem's existence. In several plants, the writer has estimated the stems originally to have been from 5 to 6 m. long.

Rhizomes Produced in Yuccas

In the preceding descriptions, it has been shown that the rhizomes of *Yucca glauca, Y. angustissima, Y. neomexicana,* and the majority of other capsular-fruited yuccas are horizontal or oblique, whereas those of *Y. elata* are vertical. Although the rhizomes of these species have typical stem structure and terminate in a scale-covered bud, they are covered with a thick, rough bark and do not have nodes, internodes, and scales along their surface. The only species that produces rhizomes with scalelike leaves is *Y. brevifolia.* In this species, the rhizome apparently grows very fast and numerous brittle scalelike leaves are scattered along the young, long rhizome. Nodes and internodes are lacking or inconspicuous, and all of the older rhizomes are covered with a rough, thick bark.

Within recent years, Holm *(17)* and others have suggested that the term "rhizome" should be restricted to subterranean stems, which represent

the primary axis developed directly from the plumule. It has been shown that in *Y. glauca, Y. baileyi, Y. neomexicana, Y. elata* and other capsular-fruited yuccas, the rhizomes are derived directly from the primary axis when the seedlings are quite young. In *Y. brevifolia,* however, they are produced from active tissue at the base of the aerial stem when the plant is rather old. In the fleshy-fruited yuccas, rhizomes are quite rare. Although they occasionally occur in *Y. baccata* and *Y. arizonica,* and possibly *Y. torreyi* and *Y. schidigera,* they are hardly more than a modified basal sprout. Such rhizomes are short, rarely more than 25 to 30 cm. long, stout, covered with a thick, rough bark, and terminate in a very large, blunt, scale-covered bud. They occur only on large mature plants. In all fleshy-fruited yuccas, basal sprouts are mainly derived from nodulelike growths, produced in active tissues at the base of the aerial stems. Such nodules lack a terminal bud and never exhibit any lateral growth.

Both the typical rhizomes of the capsular-fruited yuccas and the modified rhizomes of the fleshy-fruited yuccas produce scattered, aerial shoots and adventitious roots, and the nodules develop into a single basal sprout. Under the section "Transplanting and Asexual Propagation," it is shown that the nodules are useful in vegetative propagation, whereas the rhizomes appear of little or no value in such work.

Rhizomatous yuccas are characteristic of the more humid regions, but the fibrous-rooted plants are mainly limited to the drier regions. In the *Y. rupicola* alliance, *Y. rostrata* is strictly a fibrous-rooted species and occurs in the very dry parts of southwestern Texas. On the other hand, *Y. rupicola* has a well-developed rhizome and occurs in the humid xerophytic-mesophytic transitional zones in west-central Texas. Between these species is *Y. thompsoniana,* with a poorly developed rhizome growing in a slightly more humid climate than that of *Y. rostrata,* and *Y. reverchoni,* with a fairly well-developed rhizome growing in a slightly less humid area than that of *Y. rupicola. Y. whipplei* and its varieties *caespitosa* and *parishii* (?) are found in southern California, whereas variety *percursa* extends along the coast in south-central California. *Y. whipplei* var. *percursa* is rhizomatous and subjected to considerably more rainfall than *Y. whipplei* and its varieties *caespitosa* and *parishii* (?), which rarely produce rhizomes. Similar correlations between the amount of rainfall and the development of rhizomes occurs in *Y. brevifolia,* and, as a general rule, it applies to all species and forms.

RECOVERY OF HARVESTED YUCCAS

Near Kingman, Ariz., in May 1944, all sprouts of five plants of *Yucca schidigera* were removed and the trunks cut at various heights from soil level. In June 1945 the number of sprouts these plants had produced since cutting were from zero to nine, and these sprouts were from 8 to 23 cm. long.

Although the results concerning recovery of sprout formation were based on insufficient material, they indicate that the greater the injury to the shoot, the less likely the plant is to recover. Plants with only the sprouts and leaf heads removed formed many more sprouts than those plants that had stems cut as well as sprouts and leaf heads removed. In addition to having a larger recovery of sprouts, the sprouts of less damaged plants appear to be more vigorous.

On the United States Department of Agriculture Field Station grounds, at Tucumcari, N. Mex., 20 plants of *Y. glauca* (hybrids?) were cut in July 1942. The first 10 of these plants were cut just below the leaf head at ground level, and the second 10 cut 15 cm. below the soil surface. In October 1942 and June 1943, respectively, 5 and 2 more plants were cut at ground level.

Of 574 leaf heads cut from the 20 plants there were 553 sprouts after 3 years; of the 142 leaf heads cut from the 5 plants, 170 sprouts had appeared 31 months later; and of the original 52 leaf heads cut from the 2 plants, 73 sprouts appeared at the end of the year.

Thus, it is shown that harvested leaf heads of *Y. glauca* are rapidly replaced, and that frequently more heads of leaves are formed than the plant originally possessed. Although in the majority of cases the original number of leaf heads is not recovered until approximately 3 years after cutting, in many cases it is recovered within 3 months to a year. Five of the twenty plants involved in the experiment formed at 3½ months after cutting as many or more leaf heads than they originally had, and 8 of the 20 plants had more than their original number in 1 year's time.

Regardless of rapidity of recovery in the number of leaf heads, weight recovery of the leaf heads is comparatively slow. Within the 3-year period, only 54.61 percent of the original leaf-head weight was recovered in plants cut at ground level, and only 43.15 percent of the weight for those plants cut below soil level. The data indicate that total weight recovery would require approximately 5½ years in the former group of plants and 6¾ years in the latter group. However, because weight and recovery relationships of plants cut at soil level were based upon more leaf heads than the plant originally possessed, it is very likely to take considerably longer than 5½ years before these plants recover leaf heads as large as those that were cut.

There is very little evidence indicating that seasonal injury or weather conditions affect the amount or rapidity of recovery. The low percentage of recovery immediately following the October 1942 cutting indicates that plants recover less rapidly if injured late in the year. On the other hand, for 6 months following this cutting precipitation was only 0.89 inch, whereas it is normally 4.24 inches for the period. That short droughts do not affect recovery is made evident by the large growth following the June 1943 cutting. This cutting was made in the midst of an 11-month hot, dry spell, when the rainfall was approximately three-fifths normal. Total precipitation for the 3-year experimental period was 41.37 inches, compared with a long-time normal 3-year precipitation average of 49.50 inches.

In the preceding experiments, one plant formed a single inflorescence when the recovered sprout was 23 months old and another plant produced two inflorescences when the leaf heads were 36 months old.

Near Tayler Well, United States Jornada Experimental Range, Las Cruces, N. Mex., in June 1943, all heads of 40 plants of *Y. elata* were cut. Four months after harvesting, 9 of the plants showed no recovery. The remaining plants, however, had produced 129 leaf heads, whereas a total of only 97 was originally cut. Approximately 67 percent of the new leaf heads were of rhizomatous origin, and the remaining 33 percent were produced either at the apices of the cut stems or scattered along the sides of these stems. Two years after harvesting the plants had 108 leaf heads, about half of which were of rhizomatous origin and half of aerial stem origin. Forty-three percent of

the aerial-produced leaf heads originated at the apices of the cut stems and 57 percent along the sides of these stems.

On the same range, near West Well, in 1942, nine plants were harvested. All of the aerial growth of six of these plants was cut at soil level, and all leaf heads of the remaining three were cut immediately below the fresh leaves. Approximately 32 months after harvesting the plants with all aerial growth removed showed about 83 percent recovery in number of leaf heads, and the plants cut immediately below the leaves showed 90 percent recovery.

In these experiments all growing points of trunklike stems were destroyed. Although many of these stems died, it has been indicated that others formed new sprouts. Campbell and Keller *(8)* reported that all stems with growing points that have been destroyed soon die.

Although the experiments were abandoned before completion, it was estimated that recovery of leaf heads to full size would require at least 5 to 6 years and that harvested-weight renewal could not be accomplished unless rodent control measures were applied.

Many southwestern range foresters and botanists have been consulted by the writer relative to *Y. elata*'s recovery following harvesting. Although the majority of these scientists believe that *Y. elata* will recover following shoot injury or harvesting, several are of the opinion that complete recovery is improbable and that continued harvesting would soon kill the plants. An eminent Arizona ecologist (Forrest Shreve) found that following the *Y. elata* harvesting during the first World War many plants failed to recover and that only 5- to 10-percent recovery occurred in a large area near Orogrande, N. Mex. The latter failure was mainly attributed to rodent damage and to shifting sand, which killed or covered the developing shoots.

GROWTH RATES AND AGE OF YUCCAS

Campbell and Keller *(8)* reported that the leaves of *Yucca elata* grew rapidly during the first year and usually died at the end of the third or fourth year. In the nursery of the writer, the outer leaves of 4-year-old seedlings of *Y. elata, Y. glauca, Y. baileyi,* and *Y. constricta* die when the plants are approximately 4 years old. The leaf heads of these plants are about equal in size to those of the parent seed plant. The leaf heads of *Y. neomexicana* seedlings reach such maturity in 3 years. On the other hand, the leaf heads of 3-year-old seedlings of *Y. rupicola, Y. reverchoni,* and *Y. thompsoniana* are about one-half average size, and it appears that they would not be so large as those of their parental seed plant until they are at least 5 years old.

Leaf-head development of the fleshy-fruited yuccas is considerably slower than that of the capsular-fruited species. In the former group, the leaf heads of 4¼-year-old seedlings of *Y. torreyi, Y. arizonica,* and *Y. baccata* are approximately one-half parental size and all leaves are considerably smaller than those of the parents. The leaf heads of 3-year-old *Y. schidigera* and *Y. schottii* seedlings are between one-fourth and one-half parental size, while those of 3-year-old *Y. faxoniana* seedlings are quite small and less than one-fourth the size of those of the parent seed plant. It is apparent in these species that no leaf heads will be as large as those of the parent seed plant until they are 5 to 7 years or more old.

As the longevity of fresh leaves and, consequently, the size of leaf heads largely depend upon the amount of water the plant received, undoubtedly the

age of flowering is a more accurate index of leaf-head maturity. In the writer's nursery, the majority of seedlings of practically all southwestern yuccas are from 5 to 6 years old. The species that have flowered and the age at which these species flowered are as follows:

Species	*Flowering age*
Yucca rupicola	3 years and 8 months
Y. reverchoni	4 years and 10 months
Y. neomexicana	Do.
Y. constricta	Do.
Y. thompsoniana	5 years and 4 months
Y. glauca (hybrid?)	5 years and 1 month
Y. glauca (hybrid?)	6 years and 1 month
Y. arizonica	Do.
Y. elata	Do.

In all of the preceding species, only one or two of several plants flowered. At the time of flowering the leaf heads of *Y. elata, Y. glauca, Y. constricta,* and *Y. neomexicana* were slightly larger than those of average native plants, whereas the rest were about the same size as those in flowering field plants. In the first *Y. glauca* (hybrid?) two secondary leaf heads were formed shortly after flowering. Both of these secondary leaf heads flowered 10 months after their formation.

In March 1928 numerous seedlings of *Y. whipplei* from seeds collected in Claymine Canyon, Santa Ana Mountains, Calif., were set out in the Rancho Santa Ana Botanic Garden, Orange County. In 1934, when the seedlings were approximately 7 years old, Wolf *(33)* found that 7 of the 77 plants that were still alive flowered.

For *Y. elata,* Campbell and Keller *(8)* reported an average annual stem growth of 1.07 inches (2.55 cm.), with a maximum growth of 2 inches (5.0 cm.) in favorable rainy years and a minimum growth of 0.5 inch (1.3 cm.) in a dry year. In the Riverside, Calif., nursery stem growth rates are shown in table 3.

These data show that *Y. brevifolia* and its variety *jaegeriana* are the fastest growing southwestern yuccas. The annual growth of the stems of the variety ranged from 8.12 to 16.25 cm., with an average of 11.74 cm., whereas that of the species varied from 5.22 to 8.12 cm., with an average of 6.64 cm. The writer has obtained accurate records of two older plants of *Y. brevifolia* growing in Riverside, Calif. These plants were subjected to minimum irrigation and were in well-drained disintegrated granite soil. When the plants were 21 years old, their stems were unbranched and 109 and 141 cm. tall, respectively. These plants exhibit an annual growth of 5.20 and 6.74 cm., respectively, with an average of 5.94 cm. McKelvey *(24)* pointed out that information and publications of Ernest Braunton indicated that a native plant of *Y. brevifolia* grew 1 m. in 6 or 7 years.

Approximately 6-year-old seedlings of *Y. elata,* derived from plants in Vail Junction, Ariz., exhibit annual stem growths of 1.50 and 2.03 cm., and those from State College, N. Mex., show annual stem growth 1.68 to 2.20 cm. The average annual stem growth of these seedlings is 1.78 and 1.91 cm., respectively. These growth rates are somewhat lower than those reported by Campbell and Keller *(8)*. On the other hand, *Y. elata* seedlings from a plant in White Sands National Monument, N. Mex., exhibit an annual growth of 4.68 to 9.12 cm., with an average of 6.83 cm. The stems of these plants grew approximately 2.6 times as fast as those reported by Campbell and

Keller and about 3.7 times as fast as the stems of *Y. elata* seedlings at Vail Junction and State College.

Yucca schottii appears to be the fastest growing southwestern fleshy-fruited yucca. Approximately 5-year-old seedlings of three introductions of this species exhibited an annual growth range of 2.78 to 4.28 cm., with an average of 3.35 cm.

The Rancho Santa Ana Botanic Garden, Orange County, Calif., has 116 seedlings of *Y. schidigera* on a southern hillside slope of heavy gravelly loam. These plants were grown from seed collected at Tecate, San Diego County, Calif. They have not been irrigated since the young seedlings were planted on the hillside. On March 30, 1943, when the plants were approximately 15½ years old, the writer found 63 of the plants flowering. The heights of the stems of the 116 plants ranged from 0.0 cm. to 100 cm., with 30 plants having an average height of 40 cm. The annual average growth of the stems is 2.65 cm. Although none of the plants had more than one main shoot, young sprouts around the base of the old stems ranged from 0 to 7 in number, and averaged 1.62 cm. in height.

Aside from the preceding unirrigated plants, several seedlings were planted on a hilltop in more sandy soil and subjected to semi-irrigation. In the 15½ years these plants had made exceptionally good growth. The only one measured had four main stems, each of which had several leaf heads around the top, with one to three inflorescences. The four stems ranged from 40 to 120 cm. tall. The average annual growth of the tallest stem is 7.7 cm.

Campbell and Keller *(8)* concluded that growth in *Y. elata* largely depends upon the amount of rainfall and that practically all stem growth is made in the summer. Although the data from the Rancho Santa Ana Botanic Garden plants and from the writer's nursery seedlings confirm these conclusions, the variations in growth rates of individual introductions indicate that growth rates also depend upon the genetical constitution of the plants.

Very little can be said relative to the age of yuccas. McKelvey *(24)* cited Hollick *(16, p. 249)* who in reference to *Y. brevifolia* wrote, "The ages of certain individual trees have been estimated at approximately 600-800 years. The age of the largest one known, located about eighteen miles east of Lancaster, in Antelope Valley, was estimated at 1,000 years or more. It was eighty feet in height and nine feet in circumference." McKelvey also cited Sudworth *(30, p. 205)*, who in reference to *Y. schidigera* stated, "No definite statement can be made concerning the age limit of this yucca, which, however, can hardly be less long-lived than the Joshua tree. Messrs. C. R. Orcutt and S. B. Parish, who know the tree yuccas from long observation, both inform the writer [Sudworth] that the Mohave yucca is an exceedingly persistent but very slow grower in its native habitat, scarcely any change having been perceived in trees under observation for the last twenty-five years."

It is the writer's opinion that the majority of yuccas are extremely long-lived, and that plants of several species are as old or older than those of *Y. brevifolia.* It has been shown that *Y. faxoniana, Y. schidigera,* and *Y. torreyi* occasionally have stems 6.5, 2.5, and 4.3 m. tall, respectively, and that 3- or 4-year-old seedlings of these species are quite small and exhibit no stems. *Y. arizonica* occasionally produces stems 2.4 m. tall. The annual growth rate of seedling stems in this species was shown to be 0.27 cm. Based upon these measurements, the older stems of *Y. arizonica* would be approximately 880 years old. Such plants, however, are undoubtedly considerably

older, as the growing conditions of native plants are poorer than those upon which the growth rate is based and no allowance has been made for secondary leaf-head formation and stem branching.

Although the majority of rhizomatous species do not form tall stems, they often produce large clumps. Such clumps frequently cover an area of 10 to 20 square meters, and clumps covering 40 square meters or more are not uncommon in the *Y. glauca* alliance. Morphological studies of many of these clumps and of seedlings derived from several of them indicate that the majority, if not all clumps, are either a simple plant or a clone. The growth rates and slow development of clumps in seedlings, in conjunction with the large size and extreme persistence of native plants, lead the writer to believe that many of the clumps of the rhizomatous species are as old as or older than any of the stemmed yuccas.

The longevity of yuccas has undoubtedly contributed considerably to their diversity. Variations produced are preserved for many years, and, hence, their chances of spreading, intermingling, and recombining are probably greatly augmented.

TRANSPLANTING AND ASEXUAL PROPAGATION

While developing a new nursery in May 1946, the writer transplanted 2- to 3-year-old seedlings of practically all southwestern yucca species. The seedlings were simply removed bare-rooted to the new location and immediately planted and watered. All species having a fibrous root system continued to grow and exhibited no ill effects from the transplanting. Several of the plants having a rhizomatous system, however, showed a definite set-back in that the outer leaves of the leaf head died. Out of some 130 seedlings transplanted, only 2 finally died. These 2 plants were of *Yucca elata,* and upon examining them it was found that part of the rhizome of each of them had been cut off.

In the past few years, several 5- to 6-year-old seedlings of practically all species have been transplanted without a loss. These plants were transplanted at various times through the year and handled in the same manner as the preceding ones. In the rhizomatous group and *Y. brevifolia,* approximately 35 percent of the transplants exhibited dead leaves within a week and from one-fourth to one-third of their outer leaves finally died before the plants re-established themselves. In several cases apparently excess watering during the transplanting caused the outer leaves of the imbricated bud to become diseased. These leaves showed a brown band near their bases and, in a few cases, sloughed off. Such plants, however, rapidly recovered upon discontinuance of irrigation.

Young seedlings of *Y. neomexicana, Y. gilbertiana, Y. whipplei,* and *Y. baileyi* var. *navajoa* have been successfully transplanted from native concentrations to the writer's nursery. These seedlings were carefully dug and shipped in slightly moist paper. Two to three weeks elapsed between digging and planting.

Along the highways in southwestern Texas are many beautiful plants of *Y. torreyi, Y. treculeana,* and *Y. faxoniana,* which were transplanted from native concentrations. According to reliable sources the plants were given very little care following transplanting, and practically all of them survived. They are fibrous-rooted species and were from 3 to 8 feet tall when moved. The writer has been informed that a few plants of *Y. elata* were also suc-

cessfully transplanted along the highways. The transplanting of this species, however, was found to be very expensive, as the subterranean system frequently extended 4 feet into the ground and contained very few side, or feeder roots. According to the information supplied, *Y. elata* is not hard to transplant, provided the entire root [rhizome] is dug up.

Yucca baccata, Y. torreyi, and *Y. schidigera* are easily propagated by basal nodules and young sprouts. The sprouts are simply cut off close to the mother stem, preferably with a few roots; the cut side allowed to dry a few days; and planted. The growth of these cuttings appears to be normal and uninterrupted. On the other hand the writer has had very little success in asexual propagation of rhizomatous species. Many sprouts of *Y. elata, Y. glauca,* and *Y. neomexicana* have been carefully dug, cut, and planted. These sprouts frequently possessed rhizomes 0.5 to 1.0 m. long, which were well supplied with fibrous roots. Following planting, these plants were subjected to fairly heavy, light, or no irrigation. All sprouts receiving heavy irrigation died within 4 weeks after planting, whereas the majority of those having light or no irrigation died within 6 to 8 weeks. Only 1 sprout of *Y. neomexicana* and 2 of *Y. glauca* finally grew. All were from the lightly irrigated plot, where originally some 12 sprouts had been planted.

In testing the possibility of vegetative propagation in the rhizomatous species the writer selected in native concentrations three plants each of *Y. elata, Y. neomexicana,* and *Y. glauca.* The sprouts of each plant were separated from the mother stem or another sprout by a rhizome at least 50 cm. long. In each case a narrow trench was dug between the sprout and the mother stem and a 5- to 10-cm. section was removed from the rhizome. Thus, the sprout was completely separated from the mother stem. During the following year the plants were checked several times. None of the sprouts showed any effect of the separation and all of them appeared to continue normal growth. It thus appears that the losses in vegetative propagation of the rhizomatous species are mainly caused by the method of digging the sprout. The roots of such sprouts usually occur immediately below the sprout's leaf head, and it is very likely that too many of them are cut during the digging.

TABLE 3.—*Stem growth rates of some yucca species*[1] *grown at the Riverside, Calif., nursery*

Seedling and source[2]	Age[3]	Average annual growth	Annual growth	Height of stem
	Months	*Cm.*	*Cm.*	*Cm.*
Y. arizonica:				
From Nogales, Ariz.	[4] 71	0.27	1.34	8
			0	0
Y. schottii:				
From Nogales and Patagonia, Ariz.	56	3.35	2.78	[5] 13
			3.00	[6] 14
			3.85	18
			4.07	19
			4.28	20
Y. elata:				
From Vail Junction, Ariz.	71	1.78	1.50	9
			2.03	12
From State College, N. Mex.	71	1.91	1.68	10
			2.03	12
			2.20	13
From White Sands National Monument, N. Mex.	71	6.83	4.68	28
			5.23	31
			8.28	49
			9.12	54
Y. brevifolia:				
From Moronga Valley, Calif.	62	6.64	5.22	27
			6.58	34
			8.12	42
Y. brevifolia var. *jaegeriana:*				
From Pierce Ferry Road, Mohave County, Ariz.	62	11.74	8.12	42
			10.84	56
			16.25	84

[1] Equally as old seedlings of other stemmed species (*Y. faxoniana, Y. torreyi, Y. schidigera, Y. thornberi ?*, and *Y. thompsoniana*) exhibit no aerial stems.

[2] 71-month-old seedlings germinated April 10, 1943; others, except last six of *Y. schottii*, germinated Jan. 21, 1944. The six *Y. schottii* seedlings germinated July 10, 1944.

[3] At time of measurement.

[4] 4 plants.

[5] 2 plants.

[6] 3 plants.

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INDEX TO YUCCA SPECIES

[Synonyms are in *italic* type; page numbers of principal entries are set in **heavy-face** type]

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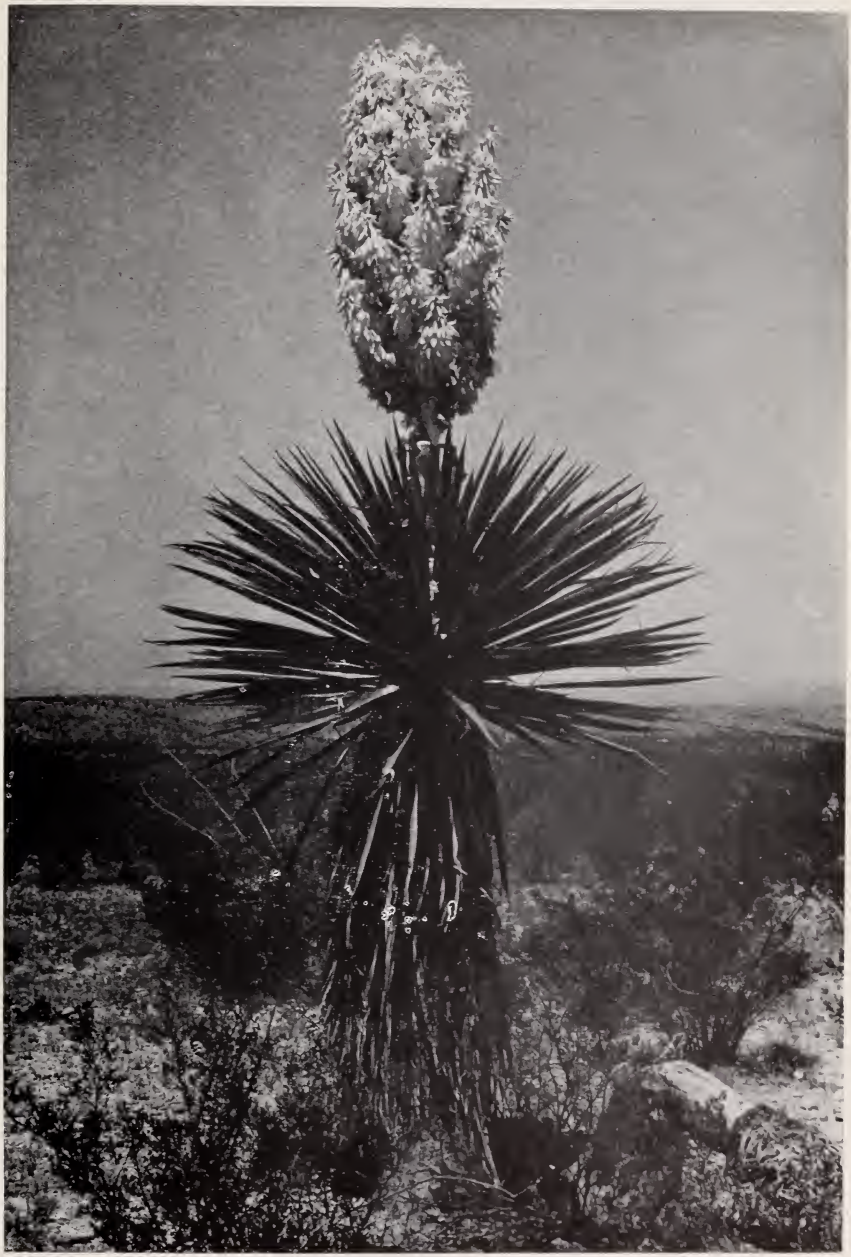


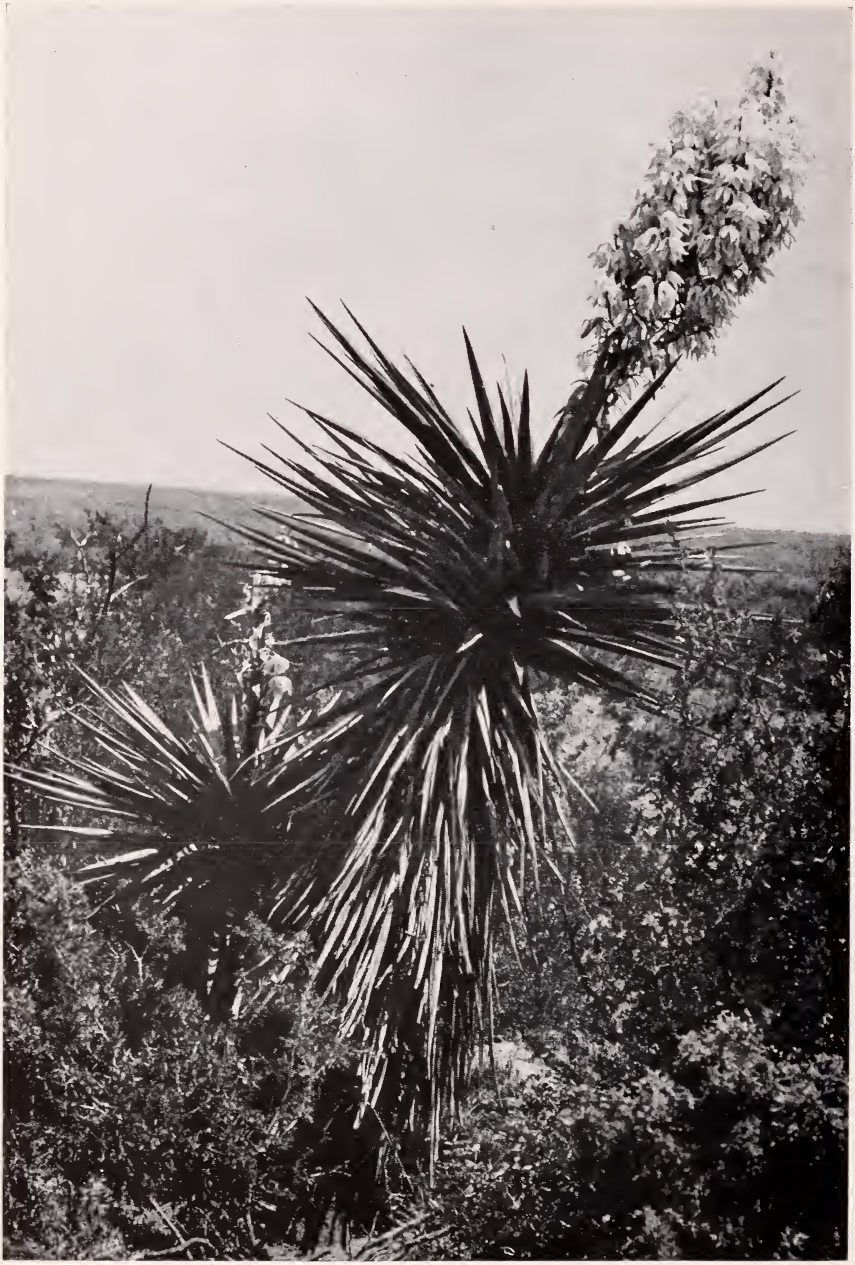
Yucca carnerosana (Trel.) McKelvey: 45 miles south of Marathon, Tex., on road to Black Gap ranch. Photographed, March 29, 1944.

Yucca carnerosana (Trel.) McKelvey: On Black Gap ranch, approximately 60 miles southeast of Marathon, Tex. Plant with five trunklike stems and five basal sprouts. Photographed, March 30, 1944.

Yucca faxoniana (Trel.) Sarg.: 9½ miles southwest of Chispa, Tex. Inflorescence immature. Photographed, April 4, 1944.

Yucca schottii Engelm.: 1 mile east of Patagonia, Ariz. Plants with several shoots and fresh leaves covering entire trunklike stems. Photographed, August 3, 1943.

Yucca schottii Engelm.: 15 miles northwest of Cloverdale, N. Mex. Plants with few shoots and fresh leaves limited to apical crown. Photographed, April 12, 1945.



Yucca treculeana Carr.: 8 miles north of Crystal City, Tex.
Photographed, March 27, 1944.

Yucca torreyi Shaf.: 3 miles east of State College, N. Mex.
Photographed, June 30, 1942.

Yucca schidigera Roezl.: On Stoddard Well-Ord Mountain road, at entrance to Boulder Mine, northeast of Victorville, Calif. Photographed, May 2, 1943.

Yucca schidigera Roezl.: Same locality as plate 8.

Yucca arizonica McKelvey: 10 miles south on Foot-Hill Trail, Combobabi, Boboquivari Mountains, Ariz. This plant exhibits falcate leaves of the blue form. Photographed, May 4, 1945.

Yucca baccata Torr.: Salt River Canyon, about 15 miles northeast of Globe, Ariz. Photographed, July 12, 1942.

Yucca baccata var. *vespertina* McKelvey: 6 miles southwest of Peach Springs, Ariz. Photographed, July 14, 1942.

Yucca baccata var. *vespertina* McKelvey: Near Mule Springs, northern end of Lanfair Valley, Mojave Desert, Calif. Photographed, May 5, 1943.

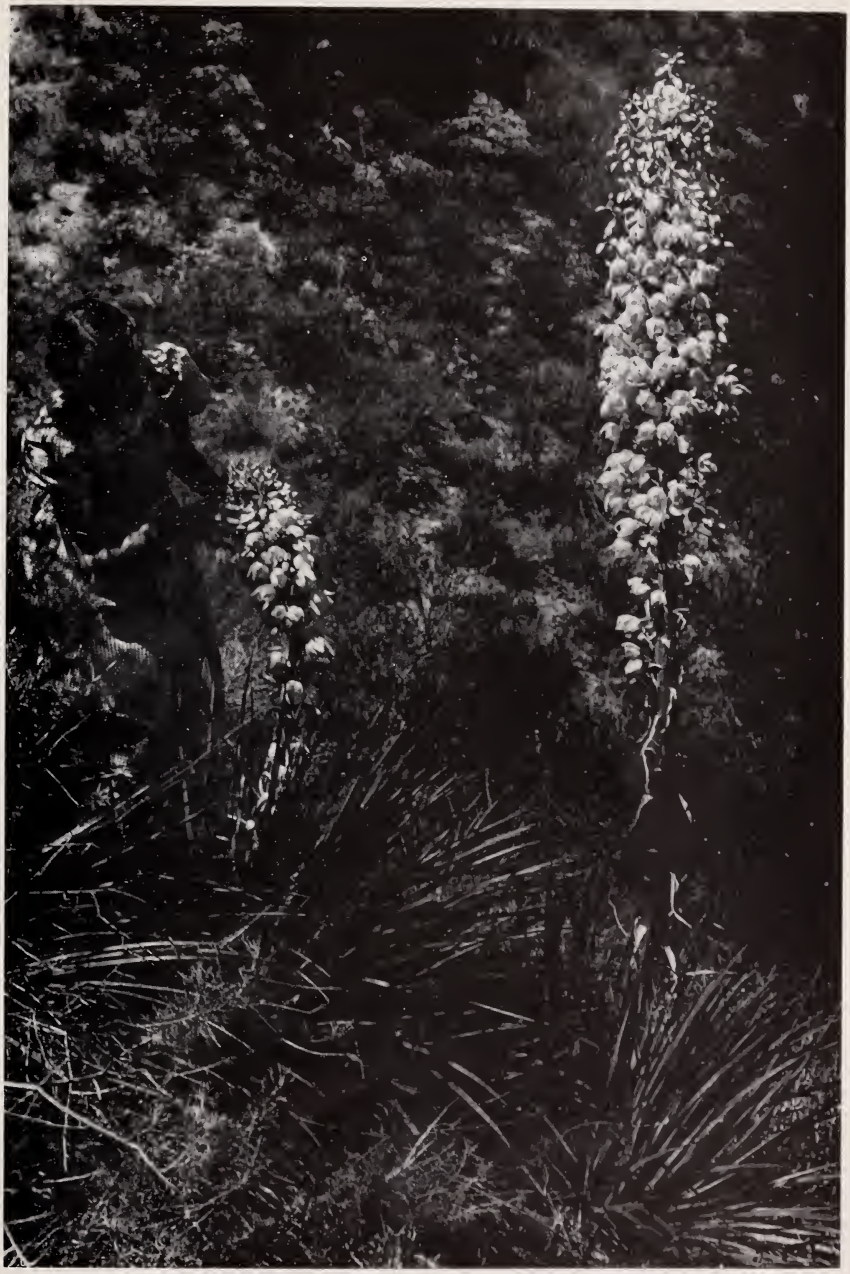
? Yucca baccata × *? Y. arizonica*: 7½ miles northeast of Douglas, Ariz. Photographed, May 12, 1945.

Yucca brevifolia Engelm.: 15 miles east of Lancaster, Calif. An exceptionally fine plant. Photographed by Ernest Braunton, July 9, 1925.

Yucca brevifolia var. *jaegeriana* McKelvey: South slope of White Hills, 3 miles east of entrance to Cyclopic Mine, Northern Mohave County, Ariz. Photographed, October 14, 1943.

Yucca brevifolia var. *jaegeriana* McKelvey: 15 miles south of Windmill Station on road to Cima, near Kessler Spring, Mojave Desert, Calif. Undoubtedly the largest concentration of yucca in United States. Photographed, May 4, 1943.

Yucca brevifolia forma *herbertii* Webber: 21 miles west of Lancaster, Calif. Photographed, April 11, 1946.



Yucca whipplei Torr.: About 7 miles west of Beaumont, Calif. Photographed, April 24, 1948.

Yucca rostrata Engelm.: Near Black Gap Ranch, about 55 miles southeast of Marathon, Tex. Photographed, March 30, 1944.

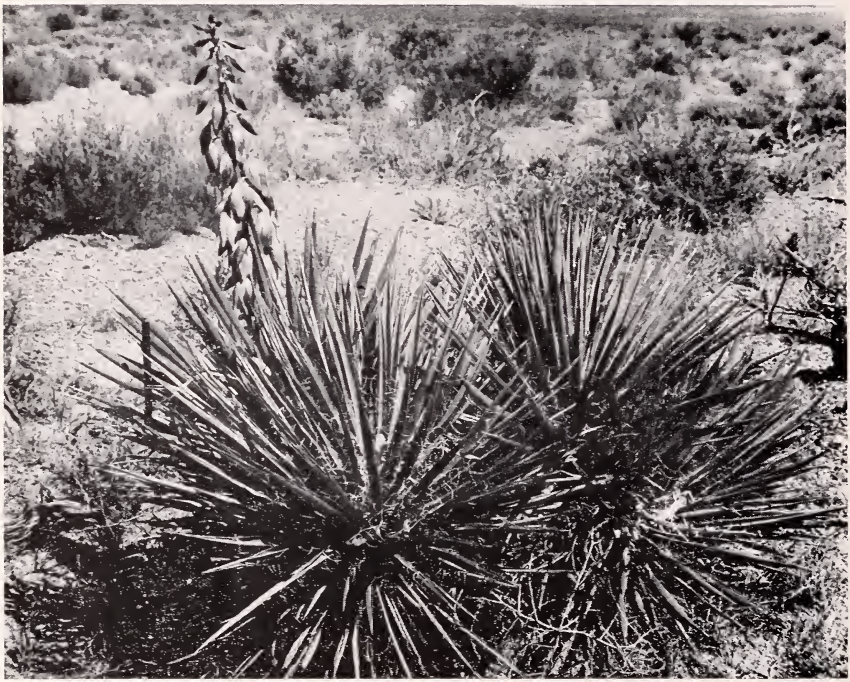
Yucca thompsoniana Trel.: 12 miles east of Fort Stockton, Tex. Photographed, May 30, 1943.

Yucca rupicola Scheele: 3 miles north of Mountain Home, Tex.
Photographed, May 21, 1945.

Yucca reverchoni Trel.: 4 miles east of Barnhart, Tex. Photographed, May 30, 1943.

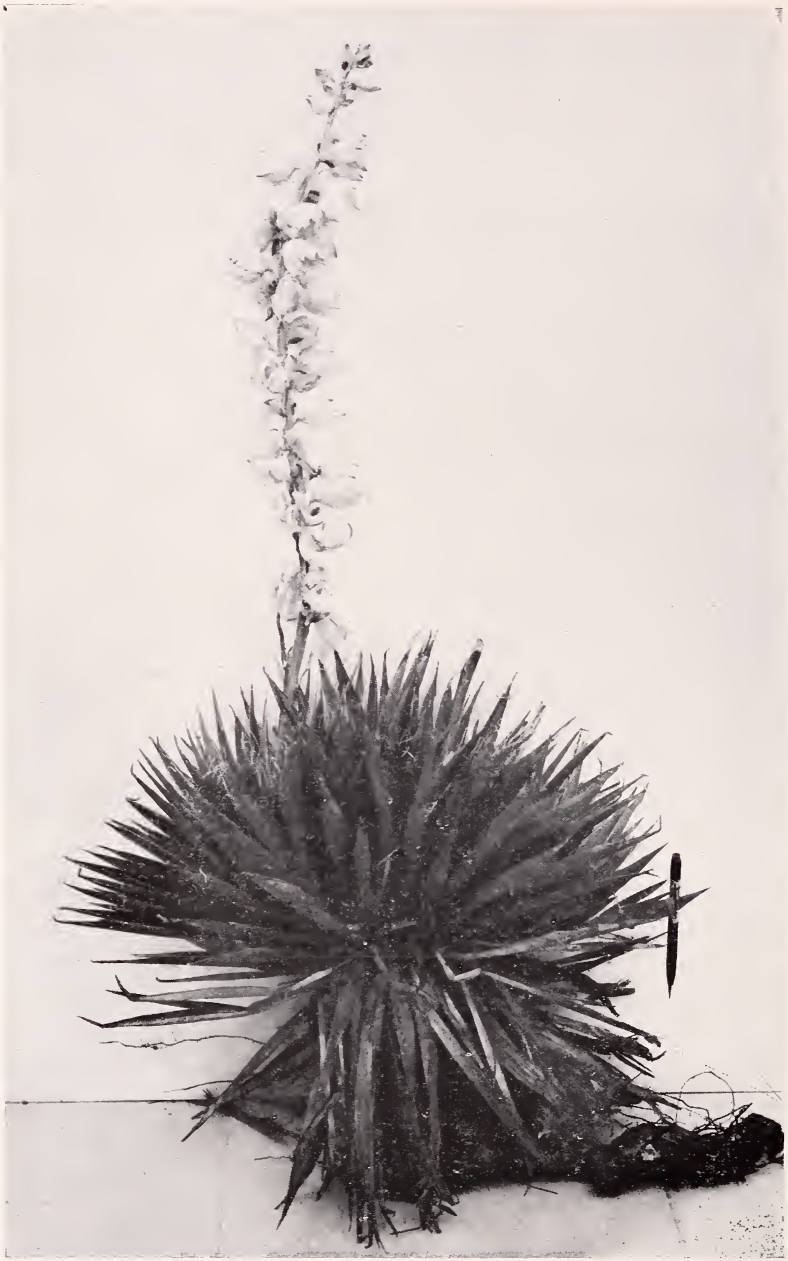
Yucca neomexicana Woot. & Standl.: 15 miles north of Moses, N. Mex. Photographed, June 6, 1944.

Yucca neomexicana Woot. & Standl.: 8 miles southeast of Kenton, Okla. Photographed, October 21, 1943.

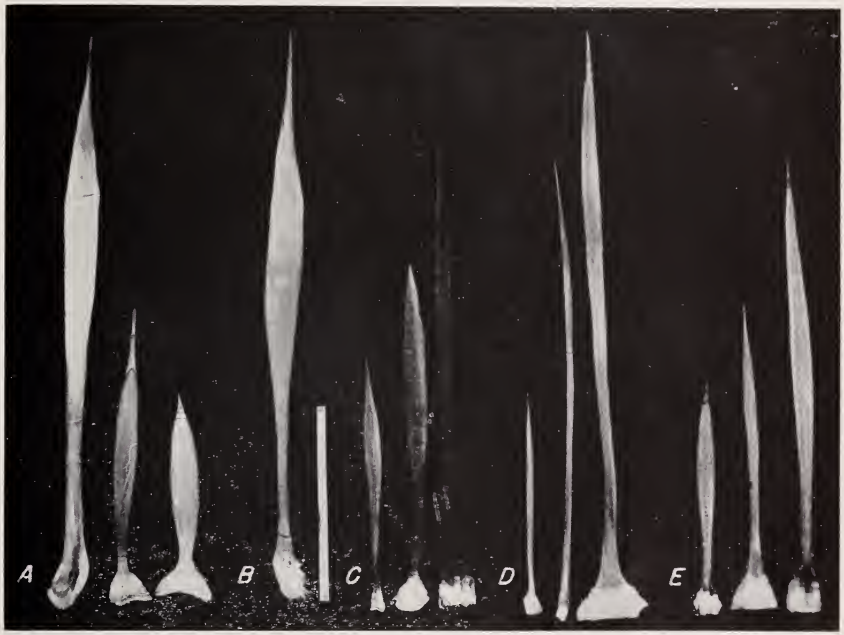


Yucca gilbertiana (Trel.) Rydb.: 37 miles west of Delta, House Range, Utah. Photographed, June 11, 1945.

Yucca gilbertiana (Trel.) Rydb.: 47 miles west of Delta, House Range, Utah. Photographed, June 11, 1945.



? *Yucca gilbertiana* × ? *Y. neomexicana*: Clark Valley about 10 miles northeast of Price, Utah. Photographed, June 6, 1947.



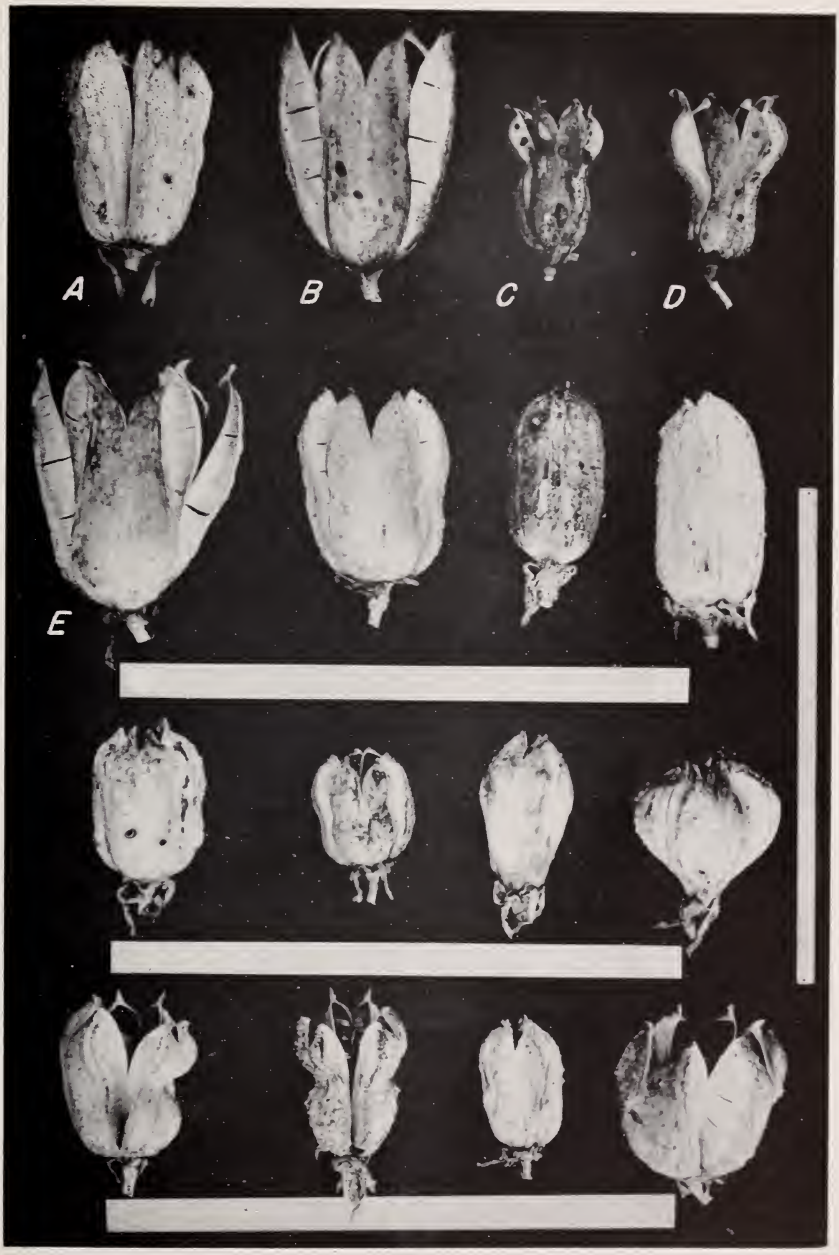
Yucca gilbertiana, Y. neomexicana, and apparent hybrids: Leaf specimens of (*A*) *Y. gilbertiana,* House Range, Utah; (*B*) apparent hybrid, Beaver, Utah; (*C*) apparent hybrid, Helper, Utah; (*D*) *Y. neomexicana* between Sapinero and Gunnison, Colo., and (*E*) *Y. neomexicana* north of Moses, N. Mex.

Yucca glauca Nutt.: Near Toonerville, Colo. Photographed, July 1, 1947, by Orville A. Parsons, Soil Conservation Service.

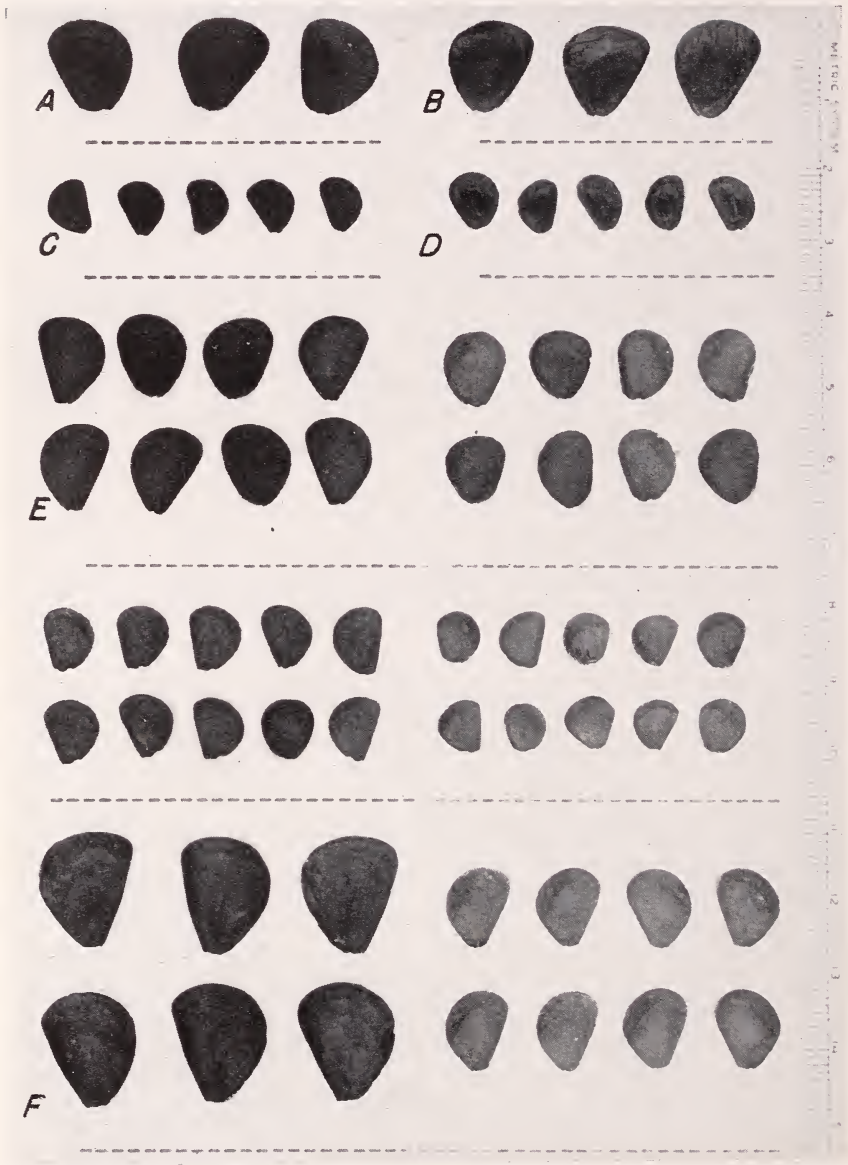
Yucca glauca alliance ? hybrid: Near Duran, N. Mex. Photographed, June 13, 1943.

Yucca glauca alliance ? hybrid: U. S. Department Agriculture Field Station, Tucumcari, N. Mex. Racemes not more than 35 cm. long. Photographed, June 3, 1944.

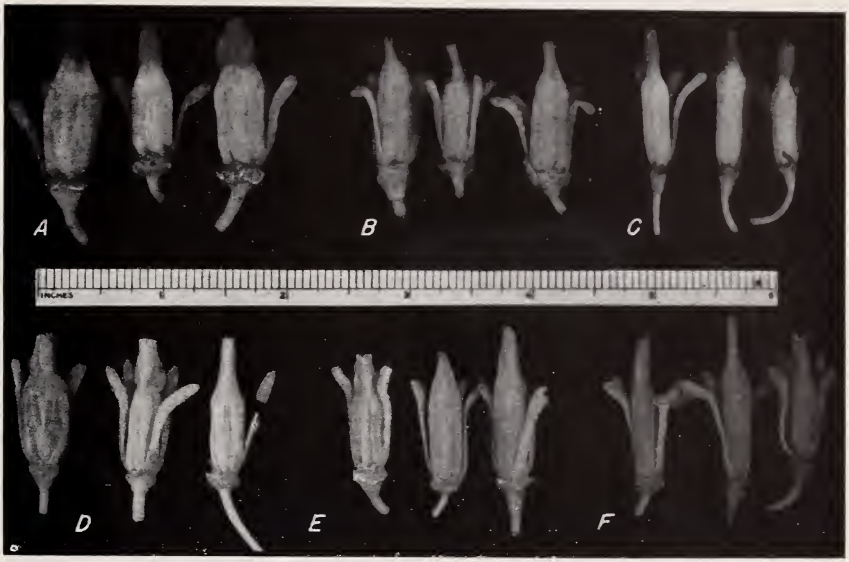
Yucca glauca alliance ? hybrid: Same locality as plate 32. Panicles broad, rather ellipsoidal; scape long. Photographed, June 5, 1944.



Capsules of *Yucca glauca* alliance: *A, Y. glauca,* Hadley, Tex.; *B, Y. baileyi,* near Holbrook, Ariz.; *C, Y. angustissima,* 30 miles east of Peach Springs, Ariz.; *D, Y. constricta,* Sterling City, Tex.; and *E,* variations in small field near Tucumcari, N. Mex.



Seed of *Yucca glauca* alliance: *A, Y. glauca,* Hadley, Tex.; *B, Y. baileyi,* Holbrook, Ariz.; *C, Y. angustissima,* 30 miles of Peach Springs, Ariz.; *D, Y. constricta,* Sterling City, Tex.; *E,* variations in small field near Tucumcari, N. Mex.; and *F,* variations near Rowe, N. Mex.



Yucca glauca alliance: Pistils and stamens of (*A*) *Y. glauca,* Hadley, Tex.; (*B*) *Y. baileyi,* 20 miles north of Gallup, N. Mex.; (*C*) *Y. constricta,* 10 miles south of Uvalde, Tex.; (*D, E, F*) apparent *Y. glauca-Y. angustissima* hybrids — (*D*) Tucumcari, N. Mex., (*E*) 26 miles southwest of Santa Fe, N. Mex., and (*F*) 12 miles west of Albuquerque, N. Mex.

Yucca elata and *? Y. elata* × *? Y. glauca* alliance: Pistils and stamens of (*A*) *Y. elata,* near Las Cruces, N. Mex.; (*B*) *Y. elata,* White Sands National Monument, N. Mex.; (*C, D*) *? Y. elata* × *? Y. glauca* — C, Hot Springs, N. Mex.; and *D,* 22 miles north of Socorro, N. Mex.; (*E, F*) *? Y. elata* × *? Y. angustissima* — *E,* Zion National Park, Utah, and *F,* 10 miles north of St. George, Utah.

? Yucca elata × *? Y. glauca* alliance: 42 miles south of Socorro, N. Mex. Photographed, June 11, 1944.

? Yucca elata × *? Y. glauca* alliance: 22 miles north of Socorro, N. Mex. Photographed, June 11, 1944.

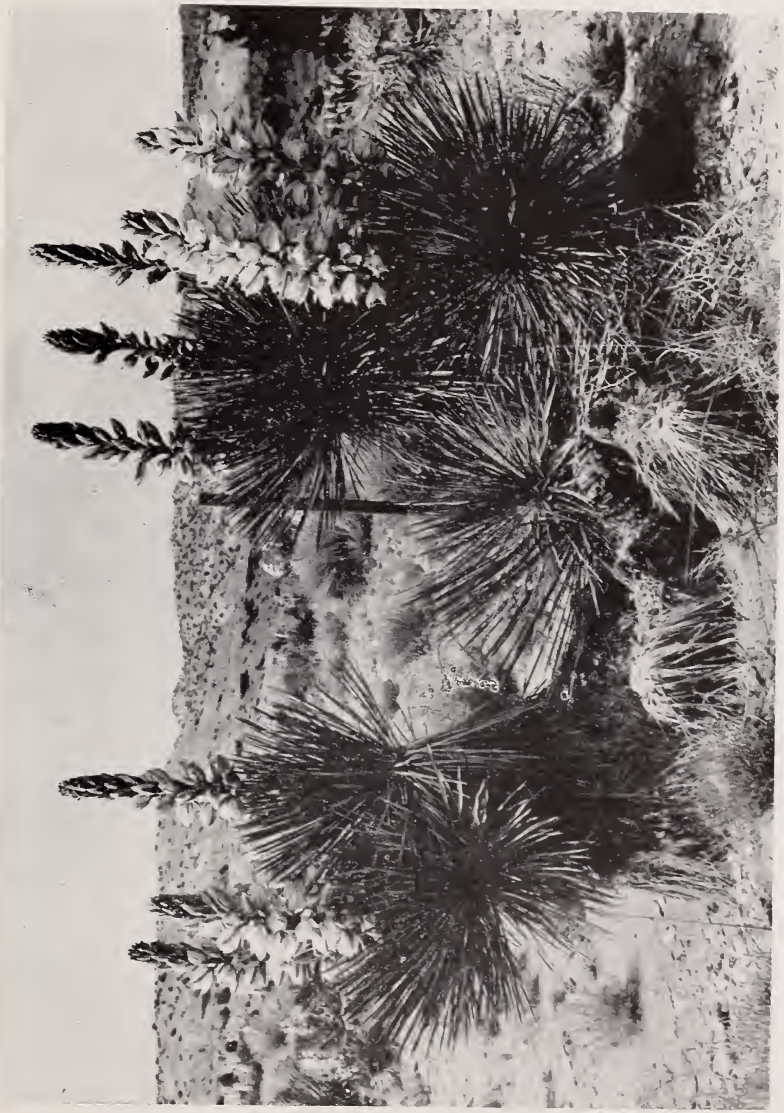
? Yucca elata × *? glauca* alliance: Same locality as plate 39. Scape thin; panicle branched at base. Photographed, June 11, 1944.

? *Yucca elata* × ♂ *Y. glauca* alliance: Same locality as plate 39, Scape thick, panicle ellipsoidal, late flowering. Photographed, June 11, 1944.

? Yucca elata × *? Y. glauca* alliance seedling: 72 months old, grown at Riverside, Calif., from seed collected near Grant, N. Mex. Raceform inflorescence.

? Yucca elata × *? Y. glauca* alliance: Sister of seedling shown in plate 42, Foliaceous, panicled inflorescence.

Yucca baileyi Woot. & Standl.: 5 miles east of Winslow, Ariz. Photographed, May 26, 1944.



Yucca baileyi var. *navajoa* Webber: 5 miles north of Tohatchi, N. Mex. Photographed, May 28, 1944.

Yucca angustissima Engelm.: 1 mile north of Paulden, Ariz.
Photographed, July 14, 1942.

Yucca constricta Buckl.: 16 miles north of Junction, Tex.
Photographed, April 7, 1944.

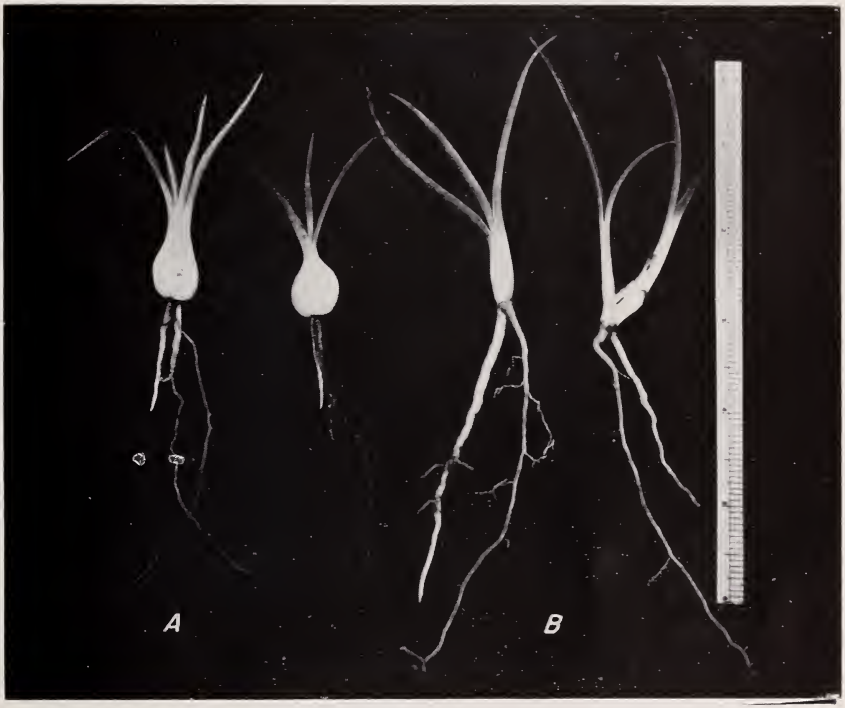
? Yucca elata × *? Y. angustissima*: About 10 miles south St. George, Utah. Photographed by R. H. Peebles, May 9, 1940.

Yucca elata Engelm.: 5 miles northwest of Separ, N. Mex. An extremely dense concentration. Photographed, June 11, 1942.

Yucca elata Engelm.: 5 miles southwest of Orogrande, N. Mex. Typical sand dune plant. Photographed, May 15, 1945.

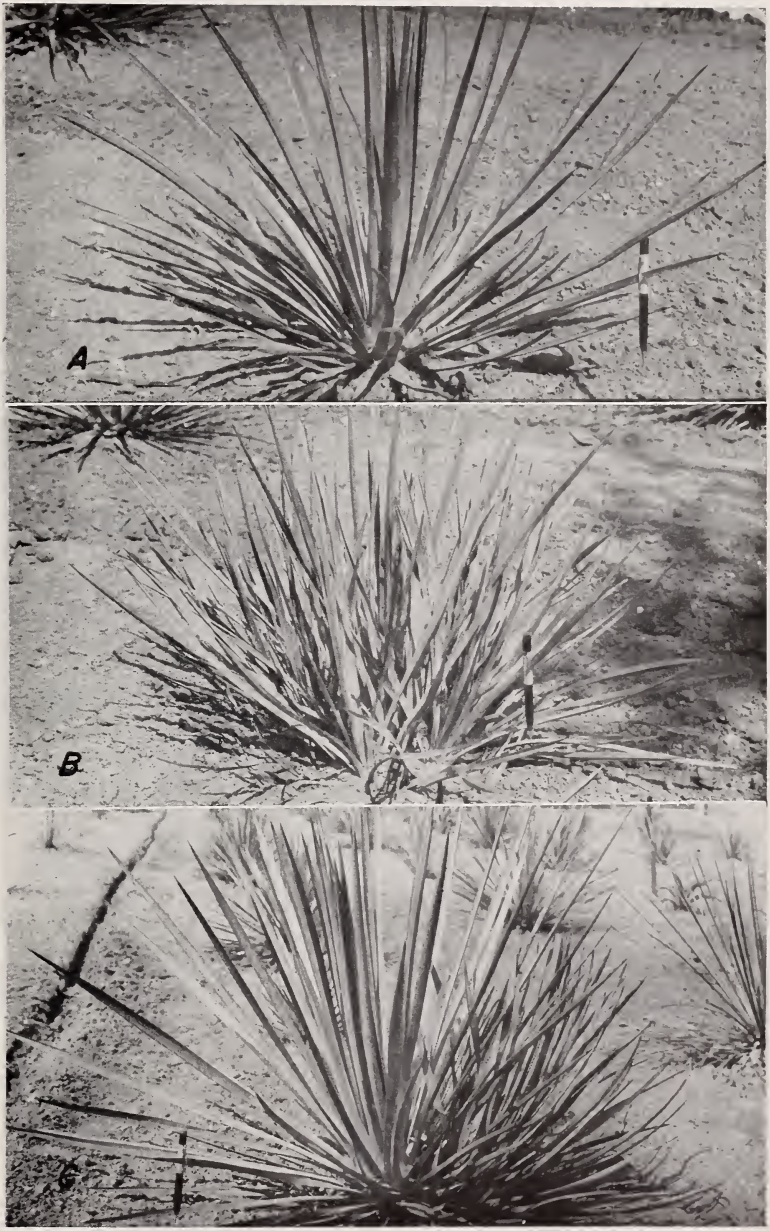
? Yucca elata × *? Y. angustissima*: 10 miles south of Cedar City, Utah. Photographed, June 13, 1945.

Yucca schottii seedlings: 6 to 34 weeks old, grown at Riverside, Calif., from seed collected near Patagonia, Ariz. Development of fibrous root system.



Yucca whipplei (*A*) and *Y. brevifolia* var. *jaegeriana* (*B*) seedlings: 6 months old, grown at Riverside, Calif., from seed collected near Beaumont, Calif., and Chloride, Ariz., respectively. Note bulblike stem of *Y. whipplei.*

Yucca baccata (*A*) and *Y. arizonica* (*B*) seedlings: 43 months old, grown at Riverside, Calif.; from seed collected near Mountain Park, N. Mex., and Nogales, Ariz., respectively. Development of sprouts from rhizomatous extensions.



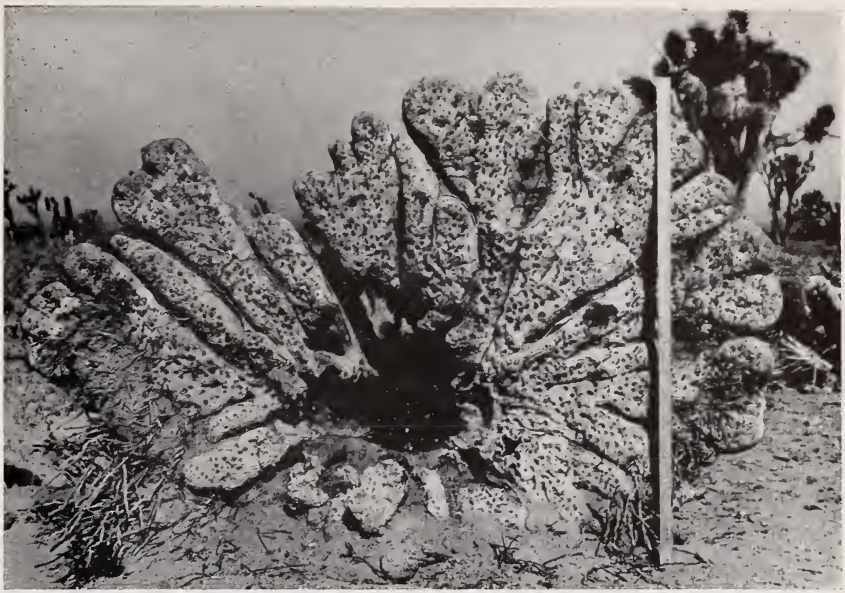
Yucca whipplei seedlings: 51-month-old sisters from plant in Cajon Pass, Calif.—*A*, a solitary segregate; *B*, a caespitose segregate; and *C*, a hybrid segregate.

Yucca faxoniana: Base of stem of old plant, 9 miles south of Chispa, Tex. Typical fibrous root system of flat base plants.

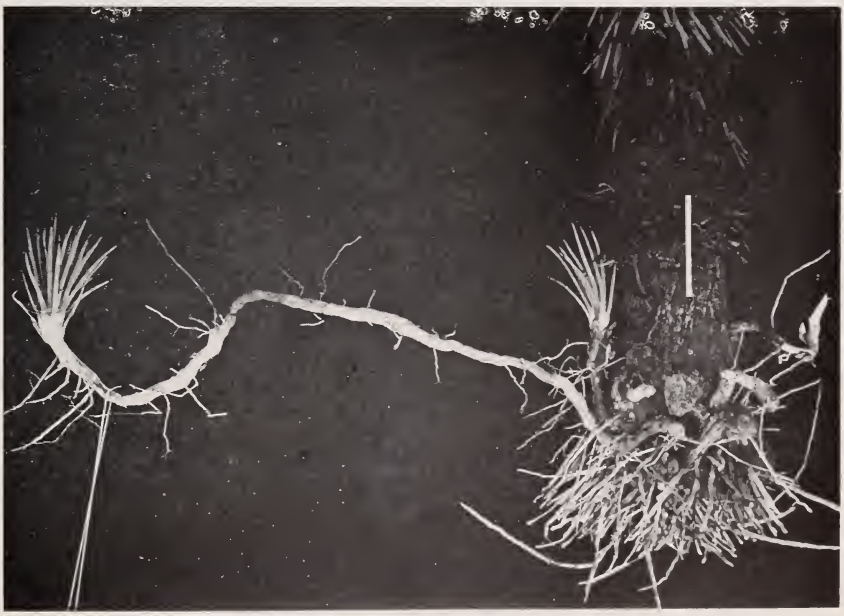
Yucca schidigera: Base of old, fallen stem, 7 miles southwest of Kingman, Ariz. Typical fibrous root system of flat base plants. Sprouts from active margin of stem-base.

Yucca torreyi: Base of old stem near State College, N. Mex. Typical fibrous root system of rounded base plants. Sprouts slightly removed from old stem.

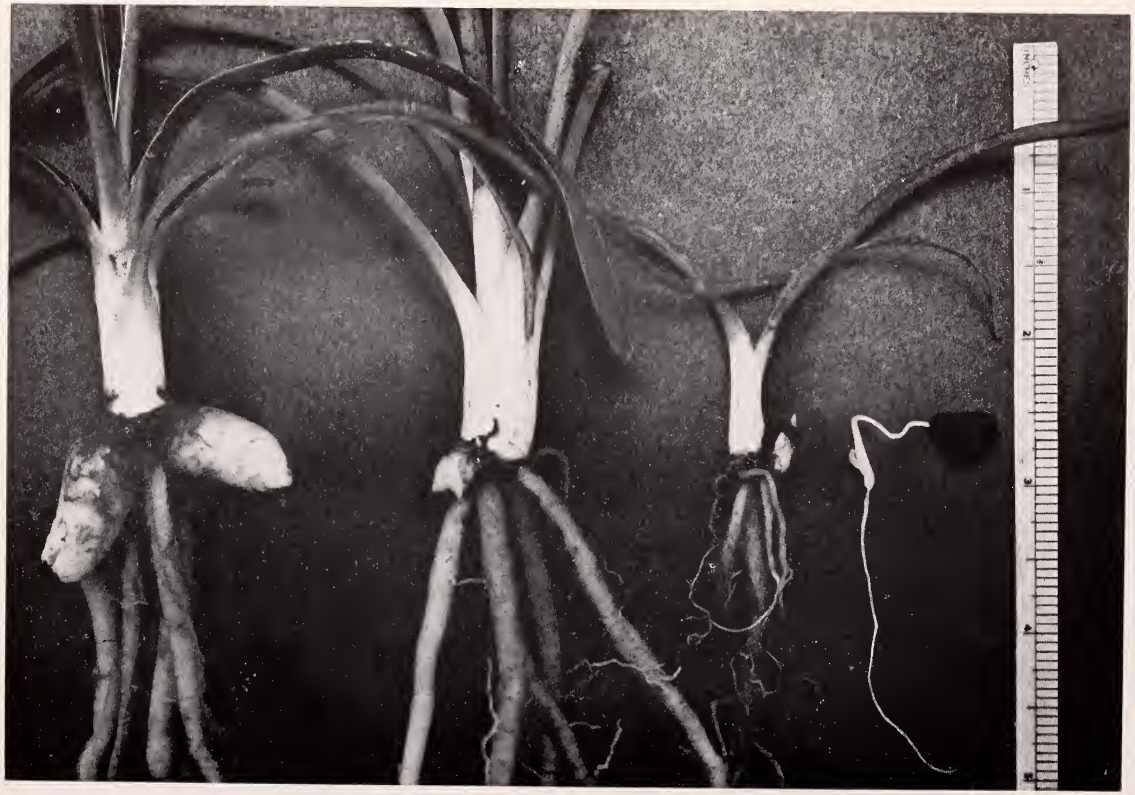
Yucca baccata: Rhizomatous and aerial stems of old plant 10 miles north of Las Cruces, N. Mex.



Yucca brevifolia var. *jaegeriana*: Base of fallen plant, 12 miles north of Cima, Calif.



Yucca brevifolia forma *herbertii*: Stem, rhizomes, and sprouts of an old plant near Twentynine Palms, Calif.



Yucca baileyi seedlings: 3 to 36 weeks old, grown at Riverside, Calif., from seed collected near Holbrook, Ariz. Development of lateral rhizome system.

Yucca glauca alliance seedlings: 15 months old, from seed collected near Grant, N. Mex. Development of lateral rhizome system.

Yucca elata seedlings: 7 months old, grown in the United States Soil Conservation Service Nursery, Tucson, Ariz. Development of vertical rhizome system.

Yucca elata seedlings: 15 months old, grown at Riverside, Calif. from seed collected in White Sands National Monument, N. Mex. Development of vertical rhizome system.

? Yucca glauca × *? Y. constricta* 20 miles west of Ozona, Tex. Lateral rhizome system.

Yucca neomexicana: 35 miles north of Clayton, N. Mex. Lateral rhizome system.

Yucca thompsoniana (*A*) and *Y. reverchoni* (*B*): *A*, Rhizomatous base of young sprout, near Bakersfield, Tex.; *B*, rhizomes of old leaf head, near San Angelo, Tex.

Yucca thompsoniana: 28 miles south of Marathon, Tex. Rhizome base of old plant.

Yucca elata: United States Jornada Range Experiment Station, Las Cruces, N. Mex. Vertical rhizome system.

Yucca elata: Shoot with adventitious roots, with old leaves at base of shoot. White Sands National Monument, N. Mex.

Yucca elata: Shoot with adventitious roots and rhizome riser at left of stem. White Sands National Monument, N. Mex.