

YUCCAS OF THE SOUTHWESTERN UNITED STATES: A STUDY IN NUMERICAL TAXONOMY AND IN ORIGINS AT THE SPECIES LEVEL

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Abstract

The lily family in general and the *Yucca* genus in particular are discussed in the context of origins. Eleven criteria are presented by which species in the genus *Yucca* may be compared. Nine *Yucca* species are contrasted using these same criteria. The results are then subjected to numerical taxonomy by which three subgroups or "sections" are established in the genus *Yucca* rather than the usual four sections proposed by other workers. Furthermore, it is asserted that the origin of these sections and species in the genus *Yucca* is not easily explained by evolutionary descent within the genus. The data of paleobotany and pollination also fail to support the origin of *Yucca* species by evolution. It is a credible alternative to evolution to suggest that the Creator endowed each particular group in this genus with its own assemblage of morphological characteristics.

Introduction to the Yuccas

Having clusters of bright cream-colored flowers and sword-shaped leaves yuccas are fascinating plants that show similarities to the agaves (century plants) and the nolinias (beargrasses). Sargent (1949, p. 110) reported that the generic name *Yucca* derives from the Carib name for the root of the Cassava. The characteristic shape of a yucca plant jutting out against the skyline is a scene familiar to all who have traveled the American deserts or the sandy, Southeastern beaches.

Yuccas have proved suitable for lawn planting and even for flower garden use. Many different varieties have been employed for such ornamental purposes, being propagated by seeds, cuttings, and offsets—see Bailey (1939, pp. 3529-31) and Clark (1979, pp. 503-5). Sargent (p. 110) has also reported that in countries where rainfall is scanty, yuccas are cultivated for hedge to protect gardens from cattle. Two of the horticultural forms most widely planted in Southern California are *Yucca gloriosa* and *Y. aloifolia* — both species native to the sand dunes of North Carolina and southward to Florida.

All members of the genus *Yucca* were natives of temperate North America from Bermuda and the Eastern Antilles westward across the South Atlantic and Gulf states on to California, as Sargent has written (p. 110). They range from 49° N latitude in southern Alberta down to 15° N latitude in southern Mexico, as indicated by Powell (1984, p. 3). They have been planted widely and have sometimes escaped from cultivation to grow wild so that their present distribution is widespread on many continents.

There are a number of economic uses to which these bizarre plants have been successfully applied. Native Americans used yuccas for making soap, rope, food, baskets, and mats—see Sargent (pp. 22 and 55). More recently these plants have been used industrially to produce stock food, heavy paper, flashing, weather stripping, burlap, and cordage as Cruse (1949, pp. 111, 114, and 129) related. He also reported that yuccas have been harvested and sometimes even cultivated as a source of saponin for soap and hair products (p. 129). In years ahead it is hoped that some further

studies on useful features of yuccas will be carried out at the CRS Grand Canyon Experiment Station, Paulden, Arizona. Readers interested in learning more about this Experiment Station should consult Howe (1984).

The Lily Family

Yuccas are all members of the lily family (Liliaceae), the classification of which has been a conundrum for botanists as will be seen in this short quotation from two leading plant taxonomists:

The Liliaceae are a complex family, however they are classified. As in other cases in which knowledge is scant, opinions have been intense. The Liliaceae include many anastomosing lines of evolution. . . . The proposed segregations emphasizing one character, then another, indicate a complex family not capable of reasonable subdivision. In short, the differentiating characters put forward so far do not yield a natural segregation. Benson and Darrow (1981, p. 46).

When these evolutionary authorities say that there is no "natural segregation" of the lily family, they mean that there is no systematic or coherent way to outline its genera by use of key characteristics—as one might expect if in fact the lily family had arisen by a branching scheme of evolutionary descent. Some other workers like Cronquist *et al.* (1977, pp. 526-27) have sought recourse from the lily family problem by isolating the yucca, agave, and nolina forms into a small separate family of their own called the Agavaceae. A similar revision has been undertaken by Wootton and Standley (1972, p. 135) who have placed the genus *Yucca* into a family called the Dracaenaceae with *Nolina* and *Dasyllirion*. Members of this truncated Agavaceae group are found in the warm, dry areas of the world and entail 20 genera divided into 450 species, as Cronquist *et al.* (p. 527) have reported. But Benson and Darrow have asserted that the erection of a small family for *Yucca* and those two other genera does not really solve the taxonomic problems or the Liliaceae as they indicated:

There have been various proposals for solving the problem by atomization of the family, but any attempt to lop off individual branches as families is based upon too little knowledge of the group as a whole to be meaningful. Accepting the entire group as a single family does not solve the problem,

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either, but the group as a whole is at least natural, and some of the fragments proposed as families are not necessarily so. Benson and Darrow (p. 46).

When they write, as above, that the entire lily family is a "natural" group, taxonomists mean that its members have a broadbased affinity for each other. Evolutionists further hold that all such members of a "natural" group have been closely related through evolutionary descent from common ancestry. Numerical taxonomists use this same phrase "natural group," however, to designate any set of organisms that resemble each other on the basis of many distinct criteria. Creationists enjoy the numerical taxonomist's usage of the word "natural" and creationists also assert that a "natural" group (like the lily family, in this case) contains organisms into which the Creator put many of the same design features. Creationists likewise affirm that such design parallelism extends to the level of chromosomes where it has been shown, for example, that the chromosome complement of all yuccas and agaves consists of a set of 25 small and five large chromosomes—a pattern which is rare in other lily family members as Cronquist (1968, p. 323) has noted.

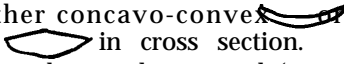

These same chromosomal characteristics are problematic for evolutionists, however, because the 25 small + five large pattern in chromosomes is not present in some of the genera like *Dracena* and *Nolina* that were originally included in the Agavaceae because of their close similarity to *Agave* and *Yucca* otherwise! To make the problem even more critical, some plants (like the plantain lily of China — *Hosta* — or the desert lily of the United States and Mexico — *Hesperocallis* which otherwise were very different from the Agavaceae) do have chromosome complements essentially like those of *Yucca* and *Agave*, as Cronquist has written (p. 323). In summary—although yuccas and agaves have a 25 + 5 chromosomal arrangement, some yucca-like plants lack this pattern while some very distant non-yucca type lily members possess it. Such a phenomenon is most confusing from an evolutionary standpoint.

Criteria for Classifying Yuccas

It is not my purpose here, however, to dwell further on these challenging problems concerning the origin of the whole lily family but to turn instead to one lily genus—the yuccas. Although there are some Mexican species and several eastern species in this genus (ranging from Texas and Oklahoma eastward to North Carolina and New Jersey), by far the greatest number of yucca species has been classified in the American Southwest. It is these southwestern American species I shall analyze.

Many excellent descriptions and keys of the southwestern yucca species have been produced. Interested readers should consult Benson and Darrow (1981), Cronquist *et al.* (1977), Kearney and Peebles (1951), Howell and McClintock (1960), McKelvey (1938), and Webber (1953) for example. Upon analysis of such treatises, it becomes apparent that the workers have designated the southwestern yuccas into groups most consistently on the basis of the following 10 criteria:

(1) leaf margins having either minute sawtoothed edges (serrations), long separating fibers, or neither.

- (2) leaves either relatively broad (2 cm or more in width) or narrow (< 2 cm in width). In Table I representative means and standard deviations are given for two "broad" and two "narrow" leaved species. The narrow vs. broad leaf nature of particular yuccas is not obvious in the photographs because all yucca leaves (whether 5 mm or 25 mm broad) look like narrow ribbons at a distance.
- (3) leaf color either blue-green or yellow-green.
- (4) leaf either concavo-convex  or plano-convex  in cross section.
- (5) trunk upright, on the ground (procumbent), or absent.
- (6) flower stalk either unbranched (a raceme) or branched (a panicle).
- (7) flower stem (inflorescence) either short and somewhat enclosed by the leaves or relatively long and visible clearly beyond the terminal cluster of leaves.
- (8) fruit either erect or non-erect on the inflorescence.
- (9) fruit either splitting open at maturity (dehiscent) or not (indehiscent).
- (10) fruit either falling after becoming ripe (deciduous) or not falling (persistent).

Other criteria involving the size and color of flower parts and the length of leaves were not employed in the present study as they were less consistently used by the aforementioned authorities. In addition to these 10 characters, I have noted that some southwestern yucca species consistently thrive in relatively low altitude habitats, growing along with Lower Sonoran or desert forms such as creosote bush and coach-whip "cacti" while others inhabit the more moist Upper Sonoran regions frequently mingling with higher altitude plants like pinyon pines, junipers, and scrub oaks. Therefore I have established the following additional criterion:

- (11) limited to relatively low altitudes (usually below 4,000 feet) in association with desert plants as opposed to those that thrive well above 4,000 feet altitude and mix with such plants as Utah juniper and pinyon pine.

The Species of Southwestern Yuccas that Result by Use of Such Criteria

By studying these traits, one can readily divide the southwestern yuccas into nine species as follows: *Yucca angustissima*, *Y. arizonica*, *Y. baccata*, *Y. brevifolia*, *Y. elata*, *Y. glauca*, *Y. schidigera*, *Y. schottii*, and *Y. whipplei*. The reader is introduced to some of these yuccas in a photographic essay involving the Cover Photograph and Figures 1-8.

Earlier authorities like Webber (1953) and McKelvey (1938) recognized many other southwestern species of yucca besides these nine. In more recent revisions of the genus, however, some older "species" were lumped together as merely being varieties of or hybrids between other species. For example, Howell and McClintock (p. 1043) in their recent supplement to the Arizona flora judged that *Y. newberryi* is synonymous with *Y. whipplei* while *Y. mohavensis* is also merely a synonym of *Y. schidigera*. In 1981, Benson and Darrow (p. 55) expressed their opinion that *Y. thronberi* and *Y. confinis* of earlier literature were both probably hybrids between *Y. baccata* and *Y. arizonica*.

Table I. Comparisons between nine southwestern species of yucca according to eleven contrasting traits.

SPECIES:	<i>angustissima</i>	<i>arizonica</i>	<i>baccata</i>	<i>brevifolia</i>	<i>elata</i>	<i>glauca</i>	<i>schidigera</i>	<i>schottii</i>	<i>whipplei</i>
Characteristics:									
1. leaf margin	fibers	a few fibers	fibers	serrations	fibers	fibers	fibers	no fibers no serrations	serrations
2. leaf width* in mm ± S.D. n =	narrow 4.2 ± 1.80 10	narrow	broad 22.3 ± 3.25 22	narrow 9.7 ± 1.17 20	narrow	narrow	broad 29.2 ± 3.74 10	broad	narrow
3. leaf color	blue-green	-----**	blue-green	blue-green	yellow-green	-----	yellow-green	yellow-green	blue-green
4. leaf cross section plano or concavo-convex	plano	concavo	concavo	plano	plano	plano	concavo	concavo	plano
5. trunk	absent	erect but obscurely so	procumbent	erect	erect	absent	erect	erect	absent (under-ground)
6. inflorescence character	raceme	panicle	panicle	panicle	panicle	raceme	panicle	panicle	panicle
7. inflorescence length	long	long	short	short	long	long	intermediate	intermediate	long
8. fruit stance	erect	not erect	not erect	not erect	erect	erect	not erect	not erect	erect
9. fruit splitting?	dehiscent	indehiscent	indehiscent	indehiscent	dehiscent	dehiscent	indehiscent	indehiscent	dehiscent
10. fruit fall?	deciduous	-----	deciduous	deciduous	persistent	persistent	deciduous	deciduous	persistent
11. altitude and ecological associations	high with pinyon pine and juniper	low 2000 - 4000 feet	high with pinyon pine and juniper	low with creosote bushes	low with creosote bushes	high with pinyon pine & sagebrush	low with creosote bushes	high with oak woodland	low with chaparral

*A mean followed by the standard deviation (in millimeters) is given for each of two typically "narrow leaved" species and two "broad leaved" species. n is the number of leaf width measurements taken.

**A blank line indicates that field and/or library data were not available.

Y. verdiensis, *Y. utahensis*, and *Y. kanabensis* have likewise been viewed as hybrids between *Y. elata* and some other yucca species or perhaps as mere variants of *Y. elata* — Howell and McClintock (p. 1043). *Y. navajoa* is now seen as variant of *Y. bailevi* while *Y. bailevi*, *Y. standleyi*, and *Y. harrimanae* are currently thought to be transitional forms between *Y. elata* and *Y. glauca* — see Howell and McClintock (p. 1943) as well as Benson and Darrow (p. 49). Finally, *Y. torreyi* may be just a variety of the species *Y. baccata* as Benson and Darrow (p. 56) also suggested.

Yuccas and Taxonomic Splitting

This collapses the southwestern yuccas to nine species instead of dozens, thus making our study easier. It also points to the practice of taxonomic splitting which is of importance in the field of origins research. Early biologists regularly practiced "splitting" whereby they erected species groups upon the basis of only slight morphological differences. Before origins discussions can center intelligently on any botanical group, it is necessary to scale down the number of taxa as has been done here. But while most authorities would propose a smaller number of species groups than were originally recognized for yuccas, not all of those authorities would agree on the number nine or on the exact identity of the nine listed here. This is not surprising, however, as there is regular disagreement



Figure 1. *Yucca brevifolia*, "Joshua tree" is seen as one leaves the chaparral and descends slopes leading down into the Mohave Desert (near Pearblossom and Palmdale, California). While this yucca has serrated leaf margins like Spanish bayonette, its tall trunk more closely resembles the upright stem of certain other yuccas like the mohave yucca. Legend has it that as the Mormons of San Bernardino made their pilgrimage to Utah, they fancied this tree, with branches akimbo, to be a botanical Joshua directing their path through the desert to the promised land! Although it is difficult to tell the narrow-leaved yuccas from the broad leaved species on photographs like these there is a significant difference between the two. Thus the mean width for *Y. brevifolia* (a typical narrow-leaved species) is 9.7 ± 1.17 mm ($n = 20$) while the mean width of leaves for *Y. schidigera* (a broad-leaved yucca) is 29.2 ± 3.74 mm ($n = 10$) as seen in Table I.

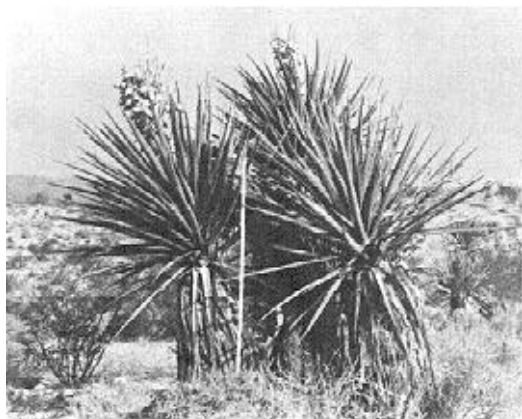


Figure 2. *Yucca schidigera*, "Mohave yucca" first meets the east-bound traveler along Interstate 15 between Victorville and Barstow, California where it is seen growing among the creosote bushes. Like several other broad leaved yuccas, this yucca has long whitish fibers separating from the margins of its leaves. But it is like the Joshua tree of a different yucca "section" or "group" as regards its upright stem seen here. The tape measure seen in this and subsequent photographs is extended 100 cm.

among taxonomists on many issues. A study of revisions in the genus yucca shows a small number of Southwestern species, something like the nine species given here (see Benson and Darrow, and Cronquist et al.).

Joneen Cockman, a taxonomist who has been identifying grasses from the CRS Grand Canyon Experiment Station, writes that "taxonomic splitting" needs closer attention from the ecological vantage as well because:

With 'rare and endangered' plants having power to hold up timber sales and thwart grazing practices on our public domain, we need to discover whether or not all the nominated plants are indeed 'rare.' Many may be the same species with some slight morphological trait adapting them to their immediate environments. (1985)

Contrasting Traits Evident Among the Nine Southwestern Yucca Species

Table I is a summary of information gathered in the field and from published reviews concerning the nine southwestern yucca species in relation to the 11 aforementioned criteria. Using such a table it is possible to erect "keys" by which any individual plant can be correctly classified into its species. A key contains a series of paired choices which eventually lead to the correct identity of a particular plant. In *Yucca* keys the criteria of Table I are regularly used.

Mathematical Taxonomy

In addition to being useful for making keys, Table I can be analyzed to show clusters of resemblance between various species. As early as the 18th century Michel Adanson applied a method of classification that he called "la méthode naturellé" to molluscs and plants. Believing that organisms should be grouped by means of mathematical comparisons between the taxa upon the basis of many characters, he originated what has since come to be called "numerical taxonomy." By such a scheme, groups or "taxa" are ultimately erected by correlating many features that organisms hold in common.

In Adansonian or numerical taxonomy, many features are put together on an equal basis and a simple arithmetic computation is used to decide which organisms should be segregated into subtaxa (species, for example of a particular taxon or group (e.g. genus).

In addition to providing a comprehensive footing for taxonomy, such broad-based computations helped separate taxonomy from phylogenetic evolutionary speculations. After 1859 evolution models became a millstone around the neck of taxonomy. Supposed evolutionary connections were employed to determine which criteria were most significant in classification. Other criteria were ignored or minimized in importance. Thus taxonomists after Darwin tried to produce classifications of even the worst known groups—based on supposed evolutionary affinities. Often they foisted preconceived philosophical notions on the data of science and taxonomy. As a result, taxonomy became a field where evolutionary guesswork was rampant. To some workers it seemed that taxonomy had become a stepchild of evolution rather than scientific discipline in its own right after the tradition of the creationist Linnaeus.

Thus some taxonomists magnify a few traits unjustifiably, as a bacterial taxonomist, Cowan, has so cleverly asserted:

A hitherto undetected similarity exists between Lewis Carroll's Alice and bacterial taxonomists in particular. Alice lived (or dreamed) in a world of fantasy in which the eating or drinking of various delicacies gave her the ability to magnify or minimize characters, and she not only upset preconceived ideas of relationships in size, but also disturbed the significance or importance attached to hereditary factors (such as monarchy) and the normal (as distinct from the decapitate) state of the whole organism. Taxonomists also seem to do these things, though they do not need to bite mushrooms or drink magical concoctions in the laboratory. (1969, pp. 145-51.)

In Adanson's method such overemphasis on one or only a few traits cannot take place because one tallies up the composite results by using many traits without any *a priori* decisions as to which traits are most



Figure 3. *Yucca baccata*, "banana yucca" or "datil" is first found growing at higher altitudes east of Kingman, Arizona along Interstate 40. This yucca is easily distinguished from the Mohave yucca because of its leaves that have a distinctly blue-green color (Mohave yuccas are yellow-green) and its stem which usually lies upon the ground; a condition that botanists call "procumbent."



Figure 4. *Yucca baccata* “banana yucca” again seen here bears large, pulpy, banana-like fruit seen here hanging downward. Used as a staple food source by certain Native Americans, these pods are said to have a very fragrant and appetizing smell as they are roasted. While they are like the other broad-leaved yuccas of group two in many ways, banana yuccas differ from each member of that group so that it is difficult to affirm that these yucca groups arose by an evolutionary scheme of descent.

meaningful or of greatest “phylogenetic” significance. The results of such numerical taxonomy can then be employed by either creationists or evolutionists depending on the origins model and philosophy involved. Readers seeking a more comprehensive introduction to numerical taxonomy may consult Sokal and Sneath (1963) as well as Ainsworth and Sneath (1962).

Mathematical Taxonomy and the Southwestern Yuccas

To apply numerical taxonomy to the nine southwestern yucca species using the 11 characteristics listed, one simply compares a particular species like *Y. angustissima* with another such as *Y. arizonica*. The number of characteristics which is possessed in common by both of those species (three in this case) is tallied and divided by the total number of characters (only nine in the comparison between *angustissima* and *arizonica* because data on traits three and 10 were not available for *arizonica*) to produce a “similarity coefficient” which in this case $3/9$, 0.33, or simply 33. Thus a numerical taxonomist would say, based on these data, that the “similarity coefficient” for *angustissima* compared to *arizonica* is 33. In another example, the similarity coefficient for *Y. angustissima* as compared to *Y. baccata* is 4 out of 11, $4/11$, 0.37, or simply 37.

This aforementioned process was repeated for every pair of species to calculate their corresponding similarity coefficients. Then, following the methods of Sokal and Sneath, one produces a “similarity matrix” in which the taxa have not been grouped—see Table II. They suggest next that by skillful rearrangement a sequence of taxa should be established in which clusters of similarity can be more easily seen:

One can then visualize the search for group structure as a rearranging of the rows or columns of this matrix in such a way as to obtain the optimum structure in the system. Sokal and Sneath p. 178).

An example of such a “cleaned up” diagram or matrix is shown in Table III. The same information becomes more graphic when shading is used for different degrees of similarity—Table IV.

Three general outlines of similarity become obvious if one puts into the same group all species that have similarity coefficients of 60 or higher with each other. This choice of 60 or above is arbitrary as is always the case in interpreting numerical taxonomic data.

Group One — *Y. angustissima*, *Y. glauca*, *Y. whipplei*, and *Y. elata*. The inclusion of *Y. elata* in this group is questionable because it has a similarity coefficient of only 55 for *Y. angustissima*. It is put here, however, because it has a high similarity coefficient for both *Y. glauca* (70) and *Y. whipplei* (73).

Group Two — dissimilar to these first four species but having a high degree of similarity among themselves are *Y. baccata*, *Y. arizonica*, *Y. schidigera*, and *Y. schottii*. As with **one** all is not completely well with **two** because the similarity coefficient for *Y. arizonica* is lower for *Y. schottii* (44) than it is for *Y. brevifolia* (56) of **three!** *Y. arizonica* is placed here tentatively, however, because of its close resemblance to *Y. schidigera* (67) and *Y. baccata* (67).

Group Three — the Joshua tree (*Y. brevifolia*) composed a group by itself because its level of similarity to any of the other species is not 60 or above. It resembles *Y. whipplei* and *Y. arizonica* most closely (56 for each) and *Y. elata* next (45). But whereas *whipplei* falls somewhat in a cluster of other species (**group one**) and *Y. arizonica* fits in with **two**, *Y. brevifolia* stands alone.

This system of three groups emerging from the numerical taxonomic use of 11 characteristics is very similar to the work of Benson and Darrow (p. 48) and of Webber (p. 16) who each proposed four major sections in the genus *Yucca* as follows:

Chaenocarpa — includes *Y. elata* and *Y. glauca*. This section corresponds closely to **group one** as Benson and Darrow felt that *angustissima* is merely a transitional form between *Y. elata* and *Y. glauca*—



Figure 5. *Yucca angustissima*, “narrow leaved yucca” thrives at altitudes above 4000 feet and thus shares territory with the banana yucca. It is readily distinguished from another narrow leaved species (*Yucca elata*) in that it has no trunk and it bears flowers in an unbranched series called a “raceme” by botanists. Note how it, like Spanish bayonette, bears its fruit standing erect. It is seen here growing on the land adjacent to the north border of the CRS Grand Canyon Experiment Station, Paulden, Arizona. Our station will most likely be an excellent location for growing several species of yuccas and the well which has been shown to produce 20 gallons per minute should be adequate for irrigating such study plots in years ahead.

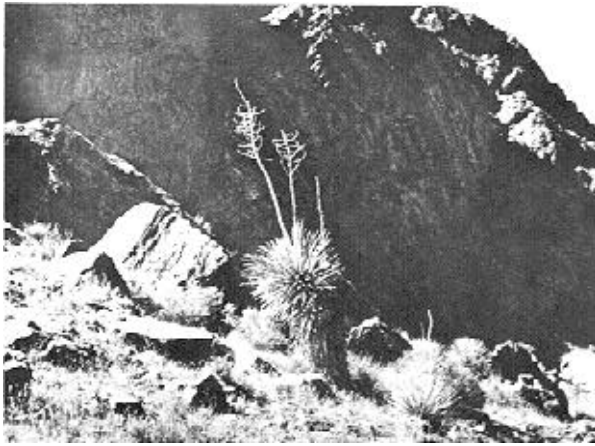


Figure 6. *Yucca elata*, "soaptree yucca" has saponins (natural detergents) in its roots which have been ground up and used as soap by Native Americans who have found that it produces a thick, cleansing lather. It has been harvested and used commercially in the manufacture of shampoo. Although similar to the narrow leaved Yucca (Figure 5) in many ways, soaptree yucca has an erect stem and produces its flowers on a branching stalk known to botanists as a "panicle." Soaptree yucca is generally not listed as a Grand Canyon plant but I have found it growing near the Colorado River, along the eastern portions of "River Trail," which connects the Bright Angel and South Kaibab Trails at the bottom of the South rim hike as seen here. Some writers consider the little narrow leaved yucca (Figure 5) to be nothing more than a transitional form between *Y. glauca* of the great plains and *Yucca elata* seen here. Yet even though the narrow leaved yucca thrives near the South Rim itself at Tusayan, Arizona (altitude about 7000 feet) and the soaptree yucca, as stated, thrives along the Colorado River (altitude about 2500 feet) there is no evidence of transitional forms between them at intermediate altitudes along the South Kaibab or Bright Angel Trails. More work is needed to assess the degree of reproductive isolation between *angustissima*, *elata*, and *glauca*. For an expanded treatment of plants along Grand Canyon trails, consult Howe (1981).

a view with which I disagree. *Y. elata*, as noted above, has only an uneasy fit in this group.

Hesperoyucca — containing *Y. whipplei* alone. Note that a unique and originally unforeseen feature of this present numerical taxonomic study is the step of lumping *Y. whipplei* together with *elata*, *angustissima*, and *glauca* to which it bears fairly high degrees of resemblance—(73), (64), and (60) respectively.

Cleistocarpa — containing *Y. brevifolia* alone and hence the same as my group three.

Sarcocarpa — includes *Y. schottii*, *Y. baccata*, *Y. schidigera*, and *Y. torreyi*. This section is like my group two because Benson and Darrow did not mention *Y. arizonica* and they included *Y. torreyi*—which some would lump as a mere variety of *Y. baccata*.

The Origin of Yucca Groups

It is thus possible by means of numerical taxonomy to divide nine species of Southwestern yuccas into three groups according to their similarities and differences relative to 11 characteristics. While this has been an interesting exercise in taxonomy, one wonders what the origins significance of these three groups might be, especially since there are some serious problems with the placement of *Y. elata*, *Y. brevifolia*, and *Y. arizonica* when all is said and done. Thus the members of the present three yucca groups (or the

Table II. A similarity matrix giving similarity coefficients in pairs of Southwestern yucca species listed in simple alphabetical order. Note that *Y. elata* and *Y. baccata* (each from different groups of sections of the genus) have a very low level of similarity to each other—18. See text for method of calculating these similarity coefficients.

	<i>angustissima</i>	<i>arizonica</i>	<i>baccata</i>	<i>brevifolia</i>	<i>elata</i>	<i>glauca</i>	<i>schidigera</i>	<i>schottii</i>	<i>whipplei</i>
<i>Y. angustissima</i>	100								
<i>Y. arizonica</i>	33	100							
<i>Y. baccata</i>	37	67	100						
<i>Y. brevifolia</i>	37	56	55	100					
<i>Y. elata</i>	55	56	18	45	100				
<i>Y. glauca</i>	90	22	18	37	70	100			
<i>Y. schidigera</i>	18	67	64	55	45	20	100		
<i>Y. schottii</i>	18	44	60	45	27	20	82	100	
<i>Y. whipplei</i>	64	44	27	55	73	60	18	9	100

four groups of Benson and Darrow) do not submit easily to an evolutionary scheme of development. There is not, as one might expect from evolution, a coherent and phylogenetic distribution of traits in these three groups but instead a series of embarrassing parallelisms between members of different groups.

It might seem at first that one is a rather coherent, closely-knit group because it contains the narrow-leaved, dehiscent fruited yuccas which share several other traits such as long flower stalks, erect fruit, and (for the most part) plano-convex leaves. But note that while most of the members of one have fibrous leaf



Figure 7. The fruit of *Yucca elata* is a capsule which splits open when ripe, as seen here. For most species of Yucca, including this one, fertilization and seed development are dependent on the amazing pollinating activities of the pronuba moth, *Tegeticula yuccasella*. This is a "mutualistic" symbiotic relationship in that the moth larvae hatch and grow inside the chambers of this capsule where they move down a row, eating generous quantities of seeds. A centimeter scale is visible.

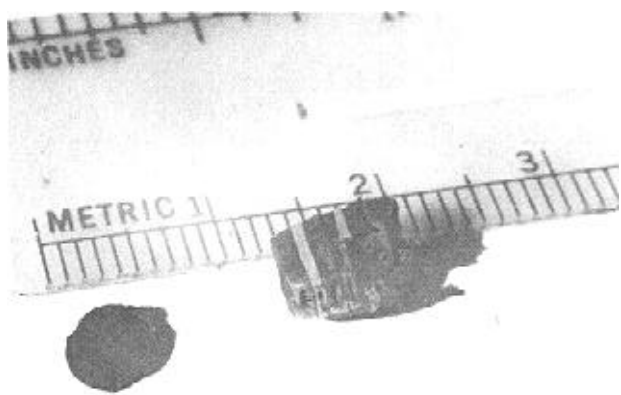


Figure 8. One seed of *Yucca elata* is seen at the left while several seeds still attached to each other as they were taken from the capsule are visible near the center of this figure.

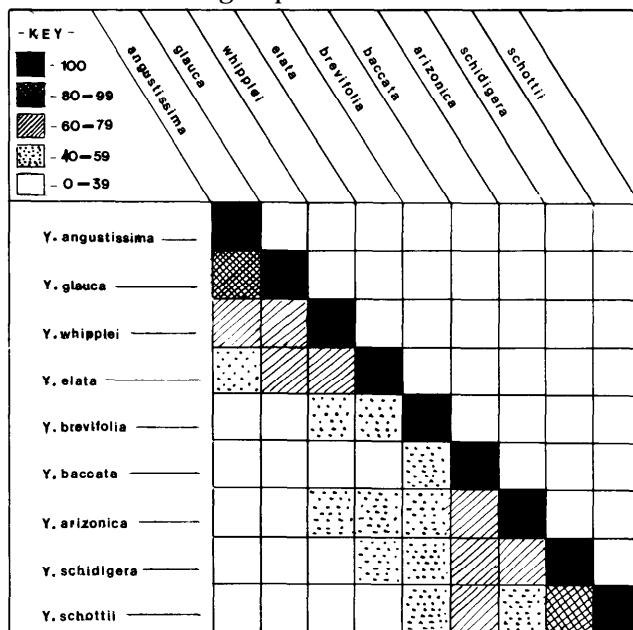
margins, *Y. whipplei* has serrated leaf margins more like *Y. brevifolia* which by itself belongs in **three**. Two of the members of **group one** thrive naturally in low regions of desert or chaparral (*whipplei* and *elata*) while the other two (*angustissima* and *glauca*) can occur in higher altitude associations like some members of **group two**. Three members of one have persistent fruits but *Y. angustissima* fruits are deciduous like those of **two**. Two members of **group one** have flowers in racemes (*Y. angustissima* and *Y. glauca*) while the other two (*Y. elata* and *Y. whipplei*) have panicles—more like the yuccas of **group two**. Three members of **group one** have no trunk (*angustissima*, *glauca*, and *whipplei*) but *elata* has a tall, sturdy trunk and is thereby very much like certain yuccas of **two** and, of course, like *brevifolia* of **three**.

Group two, on the other hand, contains the relatively broadleaved, indehiscent fruited yuccas which generally also have fibers along their leaf margins and a

Table III. A rearranged similarity matrix has been ordered to place similar species close to each other, as is the case with the first four or the last four.

	<i>angustissima</i>	<i>glauca</i>	<i>whipplei</i>	<i>elata</i>	<i>brevifolia</i>	<i>baccata</i>	<i>arizonica</i>	<i>schidigera</i>	<i>schottii</i>
<i>Y. angustissima</i>	100								
<i>Y. glauca</i>	90	100							
<i>Y. whipplei</i>	64	60	100						
<i>Y. elata</i>	55	70	73	100					
<i>Y. brevifolia</i>	37	37	55	45	100				
<i>Y. baccata</i>	37	18	27	18	55	100			
<i>Y. arizonica</i>	33	22	44	56	56	67	100		
<i>Y. schidigera</i>	18	20	18	45	55	64	67	100	
<i>Y. schottii</i>	18	20	9	27	45	60	44	82	100

Table IV. In this rearranged similarity matrix or “cluster diagram” degrees of similarity have been given graphic representation to make patches of resemblance more visible. On the basis of these data (and those of Table I from which the whole figure was derived) three groups can be established among the southwestern yuccas—the first four species make group one, the last four make group two and Joshua tree (*Y. brevifolia*) stands pretty much alone in group three.



concavo-convex leaf cross section. But as was seen with members of one above, the species in **two** vary among themselves regarding such traits as presence or absence of trunk, color of leaves, length of flower stalk, and altitude of growth—see Table I. Although *Y. schidigera* is like *Y. baccata* in many ways, *schidigera* is more like *elata* of **one** when it comes to the nature of its trunk and color of foliage. Although *Y. schottii* resembles other **group two** yuccas in many ways, it has neither fibers nor serrations along its leaf margins and hence is distinct from other yuccas of all three groups!

Thus it is not easy nor is it “scientific” to construct a tree of evolution for these nine species or three sections of southwestern yuccas. They present a hopeless (to the evolutionist) array of internal parallel features. One might wisely paraphrase Benson and Darrow’s prudent statements about the lily family (quoted earlier) as follows: The yuccas are a complex genus, however they are classified. As in other cases in which knowledge is scant, opinions have been intense. The yuccas include many anastomosing lines of evolution. . . . The proposed segregations emphasizing one character, then another, indicate a complex genus not capable of evolutionary subdivision. The differentiating characters put forward do not yield a natural segregation. While Benson and Darrow did not and perhaps would not make such a statement about the yuccas, it is entirely in keeping with the facts. Cronquist *et al.* (p. 527) put it this way: “Taxonomically, the genus is one of the most difficult in our area.”

Do The Fossils Help?

One might suppose that a study of the fossil record might clear up a few details or even supply direct answers about the origin of the genus *Yucca* as well as its sections and species but such is not the case. While Axelrod (1944, p. 118) surmised that yucca was probably part of an early Pliocene flora he has called the "Madro-Tertiary Flora," he lists no fossil yuccas in this or in his other publications as far as I could find—Axelrod (1939, and 1944).

Although Seward (1959, p. 323) and Daugherty (1941, pp. 70, 71, and plate 13) deal with a yucca-like leaf fossil called Yuccites from the upper Triassic strata, they present no evidence that these leaves are from yuccas or their progenitors. The only mention of yucca fossils I found after looking through many books was by Darrah (1959, p. 242) concerning a "... supposed *Yucca*" noted in the Citronella Flora of southern Alabama. Thus the fossil record of these plants is sketchy to say the least, and not much help in delineating origins. This comes in spite of the fact that the genus *Yucca* is thought to have originated quite recently and might therefore be expected to show a better than average fossil record.

Yucca Pollination and Origins

The yucca flower is usually pollinated by moths of the genus *Tegeticula*. The fascinating relationship between this moth and the flower is a well-known story aptly summarized here by Webber:

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. (p. 65)

It should also be mentioned that the mouthparts of these same insects are specially suited for holding the pollen masses of yucca.

One might have imagined, as early workers did, that each species of yucca would have its own species of *Tegeticula* moth:

It was predicted that many of the unusual yuccas of the southwestern United States and Mexico would be found to harbor additional species of these moths, but in general this has not proven to be the case. (Powell p. 1)

Instead, one species of moth, *Tegeticula yuccasella*, (as noted by Powell, and Powell and Mackie, 1966) is responsible for the pollination of nearly all the species (except *Y. whipplei* which is pollinated by *T. maculata* and *Y. brevifolia* which has another distinct *Tegeticula* species as pollinator). Thus it is by no means clear from an evolutionary standpoint how the species of *Yucca* could have undergone independent speciation as they are for the most part pollinated by one species of pronuba moth — *Tegeticula yuccasella*. Readers who turn to the excellent studies by Powell and Powell and Mackie will learn as well that there is another moth resembling *Tegeticula yuccasella* very closely that *does not* pollinate the yucca flower but *does* lay its eggs variously in the flower stalk or even in the fruit of yuccas. The genus name for these bogus pollinators

is *Prodoxus*. Furthermore they have noted that a third genus of moths (*Parategeticula pollenifera*) has been found to actually pollinate *Yucca schottii* but it does *not* use the *Y. schottii* ovules for oviposition. This whole study of fascinating insect-plant interactions in the genus *Yucca* could be profitably reviewed from the creationist viewpoint.

Summary

Rather than proposing evolutionary schemes as part of yucca taxonomy, taxonomists as scientists would do well to simply state that nine southwestern species of *Yucca* can be placed into three helpful groups. The evolutionary origin of these section groups or of the nine species themselves is not apparent because attempts to display lineages lead to numerous puzzling parallelisms that defy the manufacture of diagrams for evolutionary descent.

The paucity of support for macroevolution quite obviously does not in itself prove creationism. Such evolutionary chaos in trying to explain the origin of species in just one plant genus, however, ought to give sincere evolution-minded scientists much reason to consider the only viable alternative—special creationism. Perhaps the Creator endowed each of these nine species of *Yucca* with various morphological components for reasons of design and physiology not yet understood by botanists.

The actual creation of these nine species (or three groups as the case may be) might have occurred either at the time of the original creation or as a result of directed hybridization of genotypes after the global Flood catastrophe, as proposed by Lammerts and Howe (1974, pp. 227-28). When man thus hybridizes seed corn for increased production or produces by polyploidy a new strain of strawberries, he is (on a very limited scale) following in the footsteps of One who rapidly produced groups of plants and animals equipped for survival in their own environmental niches.

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STEREOCHEMICAL DESIGN IN LIPIDS

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Abstract

Creationists have successfully challenged evolutionists with the evidence of clever engineering design in optically active isomers such as the L-amino acids and D-sugars found exclusively in life forms. That these resolved isomers cannot be synthesized or maintained in significant quantities outside of living organisms has been recognized as strong evidence against any spontaneous generation of biopolymers from some primeval broth.

Nevertheless, the evidence found in geometric isomers is largely unknown in spite of the critical role played by this sort of stereoisomerism in living cells. Some biolipids found in cell membranes (phospholipids) are always in the cis —same side— configuration. While this geometry is essential for the proper functioning of cell membranes, it turns out that this cis configuration is not what we would expect to find in nature because it is the higher energy form. The trans —opposite side— configuration is the lower energy form and thus would be expected to be found.

A creationist teleological (planning and purpose apparent in design) explanation seems to be demanded by these facts. It is true that certain low probability molecules can be synthesized in the laboratory, such as certain substituted benzene ring isomers or even cis -polyethylene. However, these only serve to buttress the teleological argument since they require intelligence in planning the synthesis, fabricating and arranging the complex apparatus, environmental control, and in carrying out the stepwise chemical reactions in the presence of highly specific reagents, using controlled (not random) energy sources.

Further, the phyletic distribution of many biolipids may very well follow a mosaic pattern previously alluded to by some creationists.

Introduction

Biochemical synthetic pathways are complex, requiring pre-existing biomolecules such as enzymes, vitamins, high-energy phosphates, and nucleic acids, all of which are at least as highly ordered as the biopolymers whose origin we seek to explain. It is also recognized that intact cellular machinery is required to produce and integrate all cell functions—chromosomes, mitochondria, ribosomes, membrane networks and others.

Organized components do not fall happily together in test tubes (or soups) except in fairy tales and science fiction, Prigogine's dissipative structures notwithstanding.¹

(Ilya Prigogine, winner of a Nobel Prize in 1977, recently coauthored a book in which he claims to show theoretically how order can be generated in far from equilibrium chaotic conditions.) This holds not only for proteins and amino acids, but also for lipids. This paper will emphasize that the kind of geometric isomerism found in certain lipids is important both functionally (as in cell membrane permeability) and energetically (since the less stable form is preferred).

Geometric isomerism is seldom addressed by creationists. S. E. Aw expressed surprise that evolutionary biochemists have also more or less ignored the lipids in abiotic experiments since lipids are a widespread class of biomolecules comprising up to 70 percent dryweight of some cells. He adds that where abiotic syntheses were attempted, the results have almost

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