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CEREUS GIGANTEUS

The Giant Saguaro Cactus

ECOLOGY, BIOLOGY AND MANAGEMENT RESEARCH

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By

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PHYSICAL AND BIOLOGICAL FACTORS AFFECTING THE
MAINTENANCE AND MANAGEMENT OF THE GIANT (SAGUARO)
CACTUS, CEREUS GIGANTEUS, ENGLER

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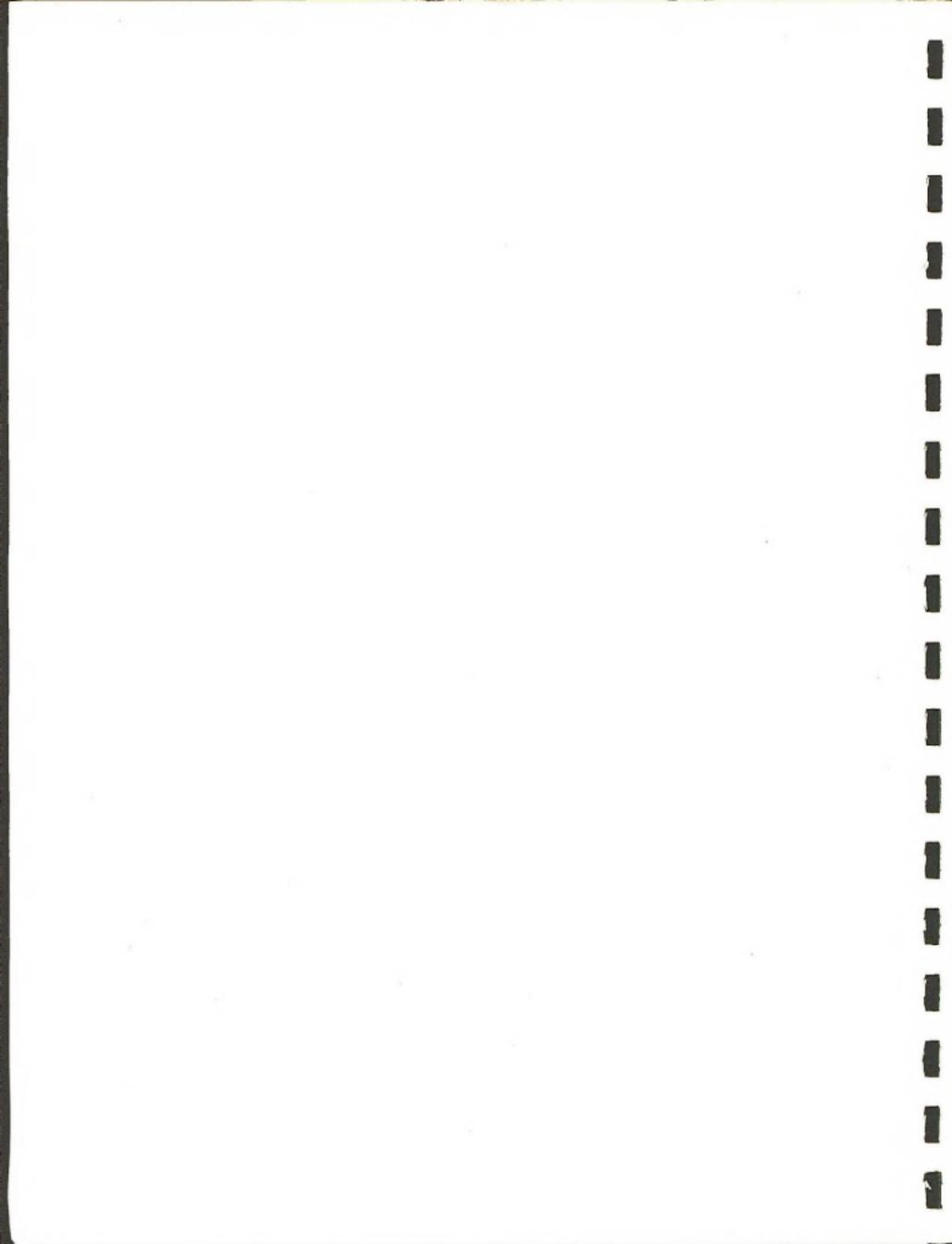
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August 30, 1972

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INTRODUCTION

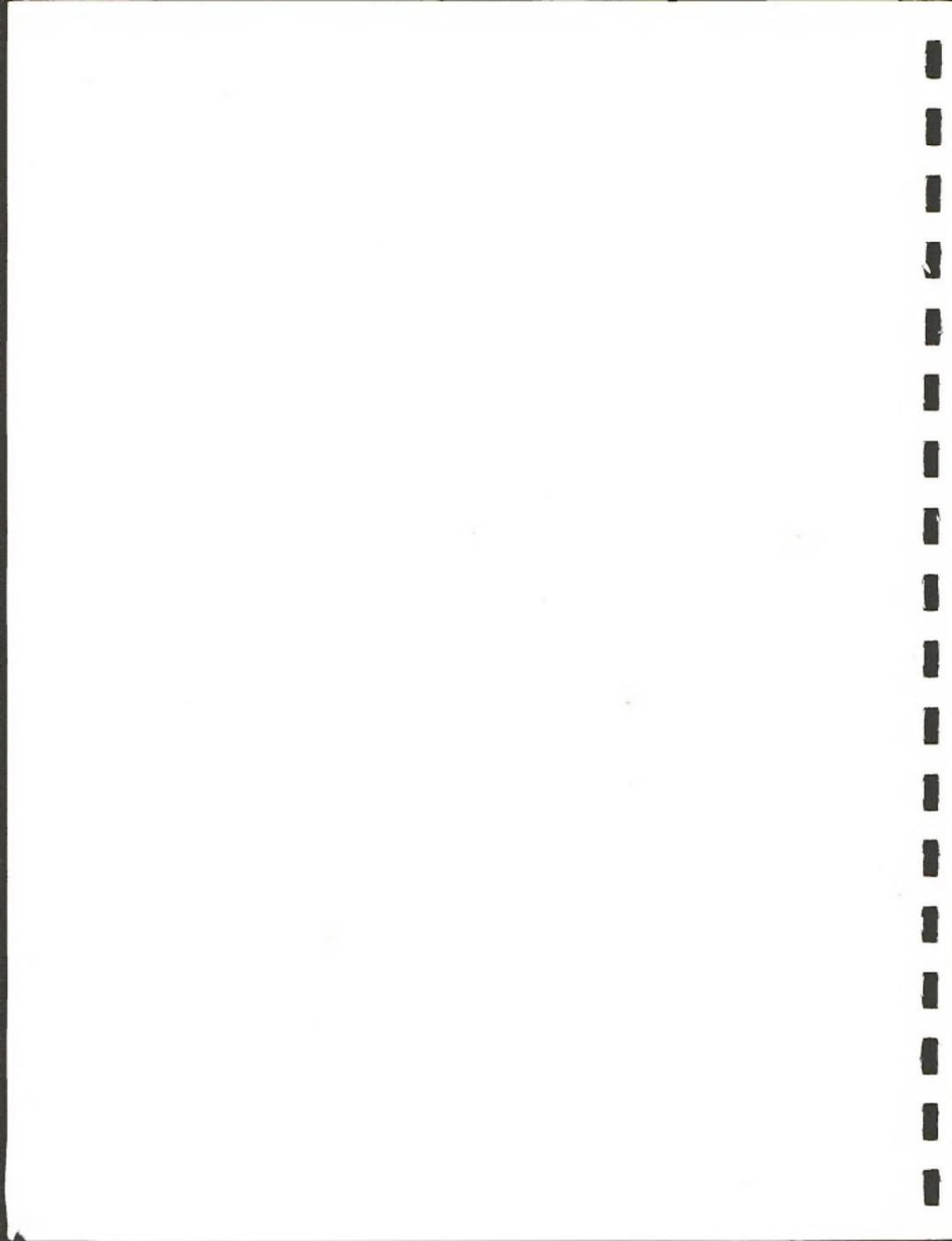
Historically speaking, one of the oldest plant species in America is found among the Cactaceae (Cacti). Cacti within this family range in all sizes, shapes and geographical distributions.

The American people have cultivated several small species of cacti; however, it was not until in the 1930's that it became necessary to place tighter controls on some of the more beautiful species due to their threat of being endangered. President Herbert Hoover by presidential proclamation created the Saguraro National Monument in 1933.

The giant cactus (Cereus giganteus), Arizona's state flower, is presently on the Arizona Commission for Agriculture and Horticulture's list of protected species and is being managed to the extent as to prohibit removal of the plants from public, Bureau of Land Management controlled, lands.

It is currently thought that this cactus should be managed and perhaps cultivated for limited public use in order to preserve the species. To carry out such an extensive management program, it is imperative that a review of the literature as well as existing research efforts by knowledgeable investigators be pursued.

It is the purpose of this publication to present an ordered, comprehensive review of published and unpublished information regarding the giant (Saguaro) cactus, Cereus giganteus.



PART I

PUBLISHED LITERATURE SUMMARY

- I. Taxonomy of the saguaro cactus and its distribution
- II. Ecology of the Cereus giganteus area
 - A. Physical Information
 - 1. Elevations
 - 2. Temperature
 - 3. Rainfall
 - 4. Edaphic conditions
 - B. Predominant plant flora of the area
 - C. Predominant Animal flora and the area
- III. General biology of the saguaro cactus
 - A. Growth requirements
 - B. Mechanism for growth and stages
 - C. Method of perpetuation
 - D. Predators
- IV. Current Management practices



The giant (Saguaro) cactus (Order-Cataceae, tribe Cereae, subtribe, Cereanae, genus and species, Cereus giganteus) (12), is endemic to the sonoran desert (fig. 1) at elevations ranging from 3000-3500 feet. The average temperature in July is 94°F, and the annual rainfall is 3-11 inches (2,3,6,7,8). The Saguaro cactus may be seen in the literature written as Carnegiea gigantea (Britton and Rose), Pilocereus giganteus (Rumpler), Pilocereus engelmanni (Engelm), or Cereus giganteus (Engelm); however, the latter is the currently accepted name.

Saguaro is distributed over rocky or gravelly soils of foothills, canyons, and benches and along washes in the Sonoran desert (5). The range of Saguaro coincides closely with the boundary of the Sonoran desert from the Colorado river east and south to the valley of the Rio Sonora. In southern California, the saguaro is found in only three localities close to the Colorado river; it has never been observed in Baja California.

In the area where Saguaro predominates, strong winds are common in rainy weather. All areas where saguaro grow do not receive the same amount nor increment of rainfall. The western edge of its distribution area is lower in altitude with a less critical temperature. In this region, the Saguaro is restricted to drainage channels because the rainfall is less than five inches annually.

One of the noted authorities on desert vegetation, Forrest Shreve, summarized the type flora within the saguaro area (2). Among the larger cacti are representatives of the genera, Pachycereus, Carnegiea and Lemaireocereus; root perennials or Ephemerals are represented by Allium kunichii A. haematociton; the Cucurbitaceae has Cucurbita digitata and Cucurbita palmata as representatives. Other representatives include Fauqueiria,



Splendem, Ferocactus, Wislizinii, and Cereus

Other dominant features of the lower sonoran (succulent desert) includes prickly pear, Cholla, palo verde, bur-sage, catclaw, cottoillo, mesquite, wild carrot, indian wheat, desert chickory and paper flower (3).

Saguaro sometimes shares itself with birds. Two species of woodpecker, the Gila Woodpecker and the Gilded Flicker, drill deep holes into the plant and build nests in its interior. In succeeding years, these nests may be taken over by Elf Owls, Sparrow Hawks, Fly Catchers or Purple Martins. Large birds build their nests among the branches of the Saguaro. Among these are the Red Tail Hawks and Great Horned Owls (13).

Rodents frequently observed in the Saguaro area include cottontails, Sylvilagus sp., ground squirrels, Citellus tereticaudus arizonae, harris ground squirrels, C. harrasi, kangaroo rats, Dipodomys sp. and porcupines, Erethizon epixanthum (3).

The saguaro cactus has been dated to live about two-hundred years. The cactus has been reported to be a very slow grower (a four inch plant averages 10-years old and a 3-foot plant may be 50-years old)(3). At maturity, the plant averages 50 feet in height, 2½ feet in diameter, 15-50 branches (5,8,15). Its root system is composed of two predominant type roots. The tap root serves as a "padding" to support the 5-10 ton plant. The radial roots radiate out from the base about one foot below the surface of the ground. The radiating distance is usually equivalent to the height of the plant (3,13).

When it rains, these roots soak up the moisture. A mature plant weighing from 5-10 tons, may take up as much as a ton of water. During dry spells, the plant gradually use this water, shrinking in girth having a wrinkled appearance due to drawing together of the vertical ridges of the stem (16).



The cactus usually blooms in June and July. The egg shaped fruits split open when ripe revealing masses of juicy, deep red pulp filled with tiny black seeds (3).

It has been reported that one out of each 275,000 saguaro seeds produces a plant. The problem is derived from several sources: trampling due to grazing and seed harvesting due to birds, ants and rodents (3, 14, 15). Rodents such as desert rats, mice and rabbits gnaw into the plant's tissues to obtain moisture; hence, the life expectancy of a young saguaro is relatively short.

The facts previously presented are of importance but need to be presented more technically. Several investigators (23, 26, 30, 31, 32, 34, 41, 42) have critically studied the intricate nature of the Saguaro habitat. Studies performed at the Saguaro National Monument east of Tucson, Arizona, have demonstrated the following facts concerning seedling germination:

- A. Germination of the tiny, black Saguaro seeds begins after the start of summer rains in July and continues through August and September (41).
- B. Germination is very dependent upon moisture and temperature with maximum germination at 25°C (32). In addition, the phenomenon of red-far red - light exposure to seeds, as demonstrated with lettuce seed (43), is a significant and required feature in Saguaro seed germination (32).



- C. Under field conditions seed germination and seedling establishment is more favorable when germinated in - shade under Palo Verde (Cercidium microphyllum), Mesquite (Prosopis juliflora) and other species (41, 26), and in rocky areas away from shade producing plants (26).
- D. Upon germination, the size and extent of seedling development is dependent upon moisture availability.
- E. The young Saguaro's are dependent upon the nurse plant for 5-10 years. The nurse plants must be perennials; hence, natural forces such as grazing and climatic changes are quite important determinate forces in the longevity of the young Saguaro (26).

Arnold et al. (30, 31, 34, 42) have done extensive studies regarding pollination requirements for the Saguaro cactus. Arnold's studies indicate that Saguaro pollination mediated by the honey bee, western white-winged dove, longnose bat and a few other agents occur at or before dawn.

In order to study Saguaro populations with reference to specie declination, growth experiments are necessary. Hastings (24, 25) has done extensive work toward establishing growth curves with reference to age for Saguaro. His findings demonstrate that measuring Saguaro on different sites for several years and mathematically expressing the growth as a differential equation followed by computer integration of the equation's inverse leads to developing a growth curve of age in years as a function of height in feet see figure 2.



Climatological data (24) indicates that Saguaro repopulation is dependent upon rainfall and freezing conditions. Young and old Saguaro's exposed to 19-36 consecutive hours of temperatures less than or equal to 32°F often suffer fatality.

Growth and population studies have led to establishing frequency curves (fig. 3) describing Saguaro populations from as far back as 1800.

Sagurao cacti mortality has been attributed to rodents (26), and weather (24, 38, 42). The first published account for Saguaro decline was done by Lightle (27). The "famed" Black Necrosis Disease caused by Erwinia carnegienana (27, 28, 29, 31, 35, 36, 37) reportedly transmitted by the cactobrosis larvae, Catobrosis fernaldialis (28, 31) has received considerable attention by Dr. Stanley Arnold and other University of Arizona scientists. Lightle's original description (21) involved the disease symptomatology and pathological histology as well as a preliminary identification of the pathogen. Boyle (28) did a complete study of the pathogen defining it more critically and linking it to being transmitted by a Lepidoptera vector, Cactobrosis fernaldialis. Her study confirmed Lightle's prognosis of the pathogen. Other studies (33, 35) have led toward blaming this disease as one important factor in Saguaro population decline. Arnold's studies (33) at the Saguaro National Monument demonstrated that on 10 acres, 29.3% of the Saguaro kill was due to the disease while other kills were due to windfall, et al. causes. During the course of the disease a hypersensitive reaction leading to callus tissue formation results-walling off the pathogen's infection progress. Chemical analysis of callus tissue suggest the presence of highly lignified dopamine containing tissues (29).



Dr. Warren Steenbergh's studies have demonstrated that the Bacterial Necrosis syndrome may not be the primary cause of Saguaro death. Controlled bacterial inoculation experiments with Saguaro's of varying ages showed that the plant would reject the bacterial attack by formation of callus tissue thus walling off the infection site preventing pathogen advancement (37).

In addition, Steenbergh's studies have indicated that lightning and freezing injury causes symptoms identical to those prevalent during Bacterial necrosis (38, 39, 40). Lowe's studies (36) have in theory complimented Steenbergh's work.

One fact that seems to be the center point is that of predisposition (i.e. prevailing conditions which are subject to cause or aid pathogen entry into an otherwise healthy plant). Hence, the main concern is whether Erwinia carnegieana is a primary or a secondary (saprophytic) pathogen. This problem is currently under strenuous debate (14, 39, 40).

Although many insects (mealy bugs, root realy bugs, red spiders, wood louse, trips, pot louse, slugs, and ants) act as pests for the young and mature Saguaro, little or no detrimental consequences result from their synergism (12).

In some areas of Arizona, management practices have leaned toward cabling some cacti species (17); however, the Saguaro situation is quite different. Management is leaning toward preservation of the species rather than partial destruction. Saguaro is in demand for landscaping by some Arizona residents. Reports have been secured by



the Arizona Commission of Agriculture and Horticulture which reveals that large quantities of desert plants are being illegally shipped. As a result, the Arizona Native Plant Law (18) has come into being. This law provides for protection of plants within the families, Liliaceae, Amaryllidaceae, Orchidaceae, Crassulaceae and Cactaceae. In addition, five genera and six plant species are included under this umbrella. Thirteen cacti and thirteen other plants are also included as protected species. The Saguaro cactus is indeed part of this list (18,20).

Unlike the Pinyon-Juniper program, Saguaro cacti are not managed extensively, preservation of the species to date is limited under the guidelines of the Arizona Plant Law.

Presently, some unpublished research exists on the Saguaro; other features of its biology, edaphic and ecological characteristics will appear in part II of this manuscript.

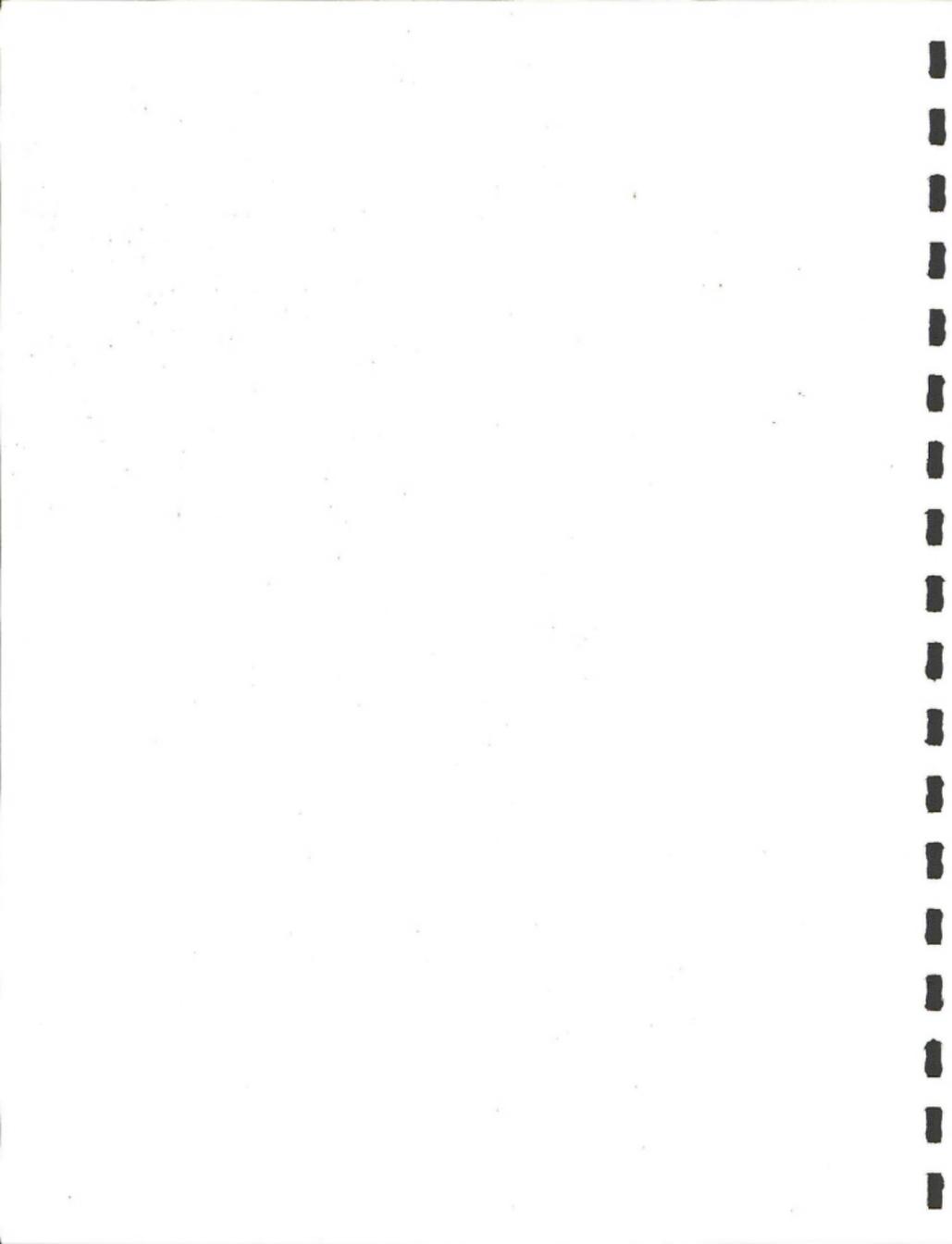


PART II

- I. Current Research Emphasis (University of Arizona Consultation)

- II. Facts concerning the Saguaro Cacti elucidated by Saguaro National Monument Officials

- III. Personal Observations in the Form of Pictures



The nucleus of Cereus giganteus research is at the University of Arizona under the direction of Drs. Alcorn, Hasting, Turner, and Mason. Consultation with these scientists (43, 44, 45, 46) revealed the following facts:

1. Growth studies on Tumamoc hill (Tucson, Ariz.) have been useful in establishing mortality data for the cactus. The graph relationship of mortality rate percentage as a function of age is found in figure 4.
2. From the curve of growth data as a function of age computer manipulation constructs a curve expressing growth as a function of time similar to the curve in figure 3.
3. Air temperature less than 45^oF restrict Saguaro water uptake.
4. Saguaro repopulation is more favored on rocky soil than on alluvial soils.
5. Saguaro growth is restricted on the north and east by cold temperatures, on the west by the Colorado River (due to a lack of biseasonal rainfall), and the south by competing species.
6. Summer and winter rainfall are major limiting growth factors.
7. The Black necrosis pathogen, Erwinia carnegiana also includes cholla, barrel, and prickly pear among its hosts. Current research indicates the need to change its name to E. caratovora f. sp. carnegiana due to its close pathological relationship to Erwinia caratovora, another soft rot pathogen.



8. As you go west out of the western part of summer rainfall areas, only 8% of the Saguaro cacti flower; hence, repopulation is very remote (22).
9. Current research emphasis involves an ecological survey of test plots in Arizona and Northern Mexico with reference to factors influencing plant cover, seed germination and transplanting.

As previously stated (Part I) the Saguaro National Monument is a "store house" and one of the major centers for Saguaro Cacti studies. Mr. Harold Jones, Supt., and Harold Coss, Chief Naturalist (47) related the following factors regarding the species.

1. The amount of rainfall in the monument is about 1-2 inches more than in Phoenix; hence, the condition of Cereus giganteus is much better in Tucson than those in Phoenix.
2. The elevation at the monument is 3100 ft.
3. The four main factors affecting Saguaro growth are lightning, windthrow, heat, and biseasonal rainfall.
4. Although growth is good in rocky soils it has been reported that some Saguaro stands appear in silt-sand soils. These Saguaros reportedly have no arms.

The final section of this part will be a pictorial description of Cereus giganteus growing in a 25 mile radius of Phoenix, Arizona, the Cordes jet. area and the following areas in Tucson, Arizona: Saguaro National Monument-East, Arizona Sonora Museum, and the University of Arizona.



PART III

- I. Present Recommendations for Management
- II. Effectiveness of Present Policies
- III. Professional Recommendations



Presently, Cereus giganteus, Engelm. is under protection by the Arizona Commission of Agriculture and Horticulture's Arizona Native Plant Law (18). Under this law, any person illegally obtaining Saguaro cacti et al. species as well as damaging the cacti in any way proven to be detrimental to the normal Saguaro physiology is liable for prosecution.

Notably on paper, the law if enforced, would just about solve most Saguaro problems; however, the present lack of total judicial cooperation as well as negligence on the part of some citizens simply compound the problem.

With the increase in the number of housing developments in the Tucson area, particularly close to the Saguaro National Monument-east, vandalism and Saguaro destruction is increasing. It is understandable that such housing developments are probably needed due to the high demand for residential lands; however, it is also understandable that such residential areas in close vicinity to a National Monument that houses a protected plant specie should bring tighter controls to insure continued protection.

The very small amount of rainfall in the Saguaro areas has caused a decreased demand for turf in home and business landscapes; hence desert flora is being used quite extensively (see figures part II). With this increased demand; vandalism of these cacti reached dangerous levels despite passage of the Arizona Native Plant Law previously cited.



In view of these factors it is important that the following recommendations for management receive attention:

I. Judicial Agreement

In view of the fact that a law exists which protects the species, it is imperative that the Bureau of Land Management in cooperation with the National Park Service seek to strengthen penalties and controls regarding vandalism and damages resulting from malicious mischief. Such penalties and controls will require the help of the appropriate authorities. It is apparent that the judges and other public responsible officials responsible for enforcing existing legislation are not fully aware of the legislation's significance; therefore, efforts should be made by the Dept. of the Interior (BLM and NPS) to "educate" these officials and demonstrate the important of specie protection.

Public Awareness of Agreement and Law

Perhaps all citizens in counties where Saguaro cacti are grown on public land are not aware of the existing legislation regarding specie protection. Hence, it is suggested that such information be made available to these people through the appropriate news media. In addition, proper education of the people on the significance of species protection should not be overlooked. This can be done simply and rather cheap through a series of newspaper articles regarding the importance of plant flora and their protection. The state BLM and BOR as well as NPS offices are adequately staffed for handling such a brief campaign.



Protection of Public Lands and National Monuments

It is feasible to have the U. S. Park Police, Forest Rangers, and other officials with arrest authority to patrol public lands harboring vast stands of Saguaro cacti. Usually, the appearance of such personnel deter any vandalism during daylight hours. It is not recommended that night patrols be done since removing a cactus 4-5 ft. in height (if not taller) requires adequate light. However, any patrolling done by the State Police in these areas would have increasing significance and effect. In addition, where feasible, any fencing of monument areas harboring vast Saguaro cacti stands should be done particularly along residential areas. Motor bikes, jeeps, dune buggies, et al. forms of off road vehicles do extensive damage to Saguaro stands (47). These vehicles destroy the smaller plants simply due to the driver's inability to see them. Therefore, use should be restricted only to marked paths officiated through some form of legislation.

Rodent Control

Small rodents (previously cited-part I) incur extensive damages to young Saguaro plants. These rodents gnaw on these cacti for moisture. Hence, strict control of these rodents need to be done in areas endemic to Saguaro. The best and cheapest way to accomplish this goal is to decrease the number of rodent predators (such as coyotes) killed per year, and in areas where the Saguaro population is very dense, predator control should be outlawed for a certain length of time followed by controlled predator control. This staggered system of predator control will do three things: 1. reduce rodent populations, 2. increase chances for Saguaro repopulation, and 3. keep predators at a desired level.



Controlled and Restricted Grazing

Cattle grazing has been noted as a major factor in Saguaro deaths due to trampling. Recognizing this fact, areas sparsely populated with Saguaro cacti should exercise controlled grazing privileges; whereas, areas heavily populated with Saguaro should have restricted grazing privileges. BLM field offices could better assess what cattle levels define controlled grazing privileges. In addition, these officials could stipulate grazing privileges where adequate grass cover exist and further stipulate termination of grazing privileges when the cover get so sparse as to cause the cattle to graze under or browse the nurse trees (e.g. Palo verde and Mesquite).

Nurse Tree Management

Evidence exists which demonstrates that Saguaro cacti seedlings only germinate and develop under nurse trees such as Palo verde and Mesquite. Therefore, proper management of these trees need be done. The management can take the form of restricting any cutting or burning of areas harboring reasonably dense stands of nurse trees in the vicinity of Saguaro growth areas.

Research

Research previously and currently undertaken has dealt primarily with the growth and life factors of the Saguaro under field conditions. If Saguaro cacti could be grown at a faster rate and made available on a commercial market this could foreseeably cause a decline in vandalism. It is recommended that University or National Park Service scientists such as Dr. William Steenbergh undertake a research program outlined to determine the following:



1. Determine the growth hormone picture of the Saguaro.
2. Determine whether artificial inducement of various growth hormones such as gibberellins, kinetin or indole acetic acid will stimulate production.
3. Determine the physiology of plant tissue differentiation and outline the requirements for this process. In addition, research regarding speeding up the differentiation process should be initiated.
4. Determine methods of vegetatively propagating old, damaged Saguaro trees.
5. Research involving Saguaro genetics could be designed to determine the following:
 - a. Chromosome number and mutation studies designed to improve its growth rate.
 - b. Breeding Saguaro endemic to regions of freezing temperatures with those Saguaro's susceptible to freezing conditions in an effort to develop a variety either tolerant or resistant to freezing conditions.

Nursery Production

Until such time as research can demonstrate increased growth measures for the Saguaro, the National Park Service and Bureau of Land Management scientists could establish nurseries for the purpose of raising Saguaro and other commercially important species for production and sales. Presently some establishments in Arizona raise and sell Saguaro on a limited scale; however, their prices are steep (\$5.50 per ft. for Saguaro-see figure section).



Establishing of more nurseries would decrease prices and decrease vandalism rates.

By exercising these eight recommendations

1. judicial agreements
2. public awareness of agreements and law
3. protection of public lands and national monuments
4. rodent control
5. controlled and restricted grazing
6. nurse tree management
7. research
8. nursery production

management of Cereus giganteus, Engelm, should be of reasonable success.



PART IV

I. SUMMARY

II. ACKNOWLEDGEMENTS



This publication was written with the hopes that the reader could develop a feeling for the needs of Saguaro Cacti management. The research in the area has been very meaningful, though incomplete. The incompleteness in research involves those areas of physiology and genetics-proposed as new endeavors in Part IV. This report is written with the hopes that the appropriate government officials become increasingly aware of not only Cereus giganteus (Engelm) but the needs of other protected or endangered species of plant or animal flora.

The outline and information presented is a result of many hours of reading and surveying deserts and mountain areas endemic to Saguaro; therefore, a nearly complete picture of the Saguaro was attempted to be put forth.

The author is indebted to the Director of the Bureau of Land Management, The Washington Office Forestry Staff and field staff of Arizona for their complete cooperation.

In addition, appreciation is due to the National Park Service personnel for their continued support throughout the project. Particular thanks is due Mr. Murl Storms, Chief, Division of Forestry, Washington Office, for designating the problem.





 Great Basin Desert

 Mojave Desert

 Sonoran Desert

Sonoran desert --
primary Saguaro region



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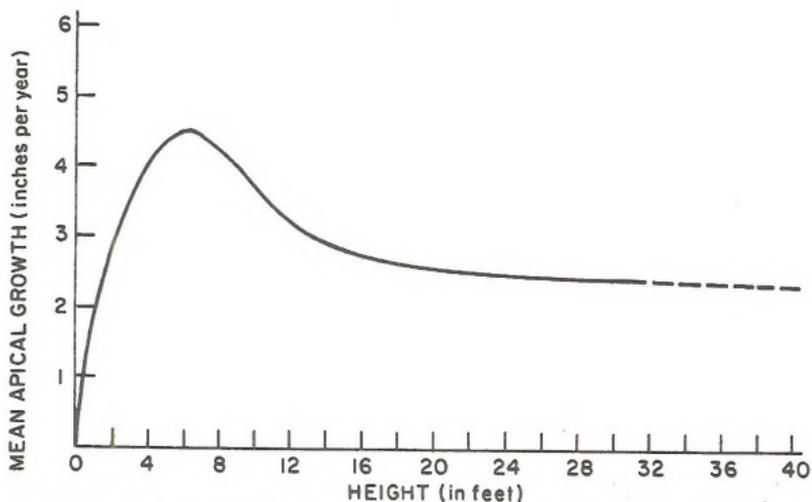


FIGURE 2. MEAN APICAL GROWTH IN SAGUAROS OF VARIOUS HEIGHTS.

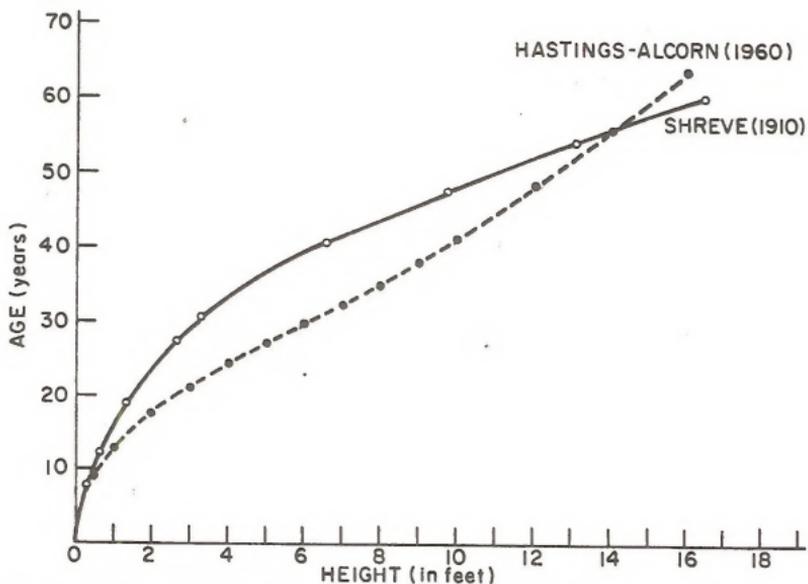


FIGURE 3. COMPARISON OF AGE-HEIGHT RELATIONSHIPS IN THE SAGUARO

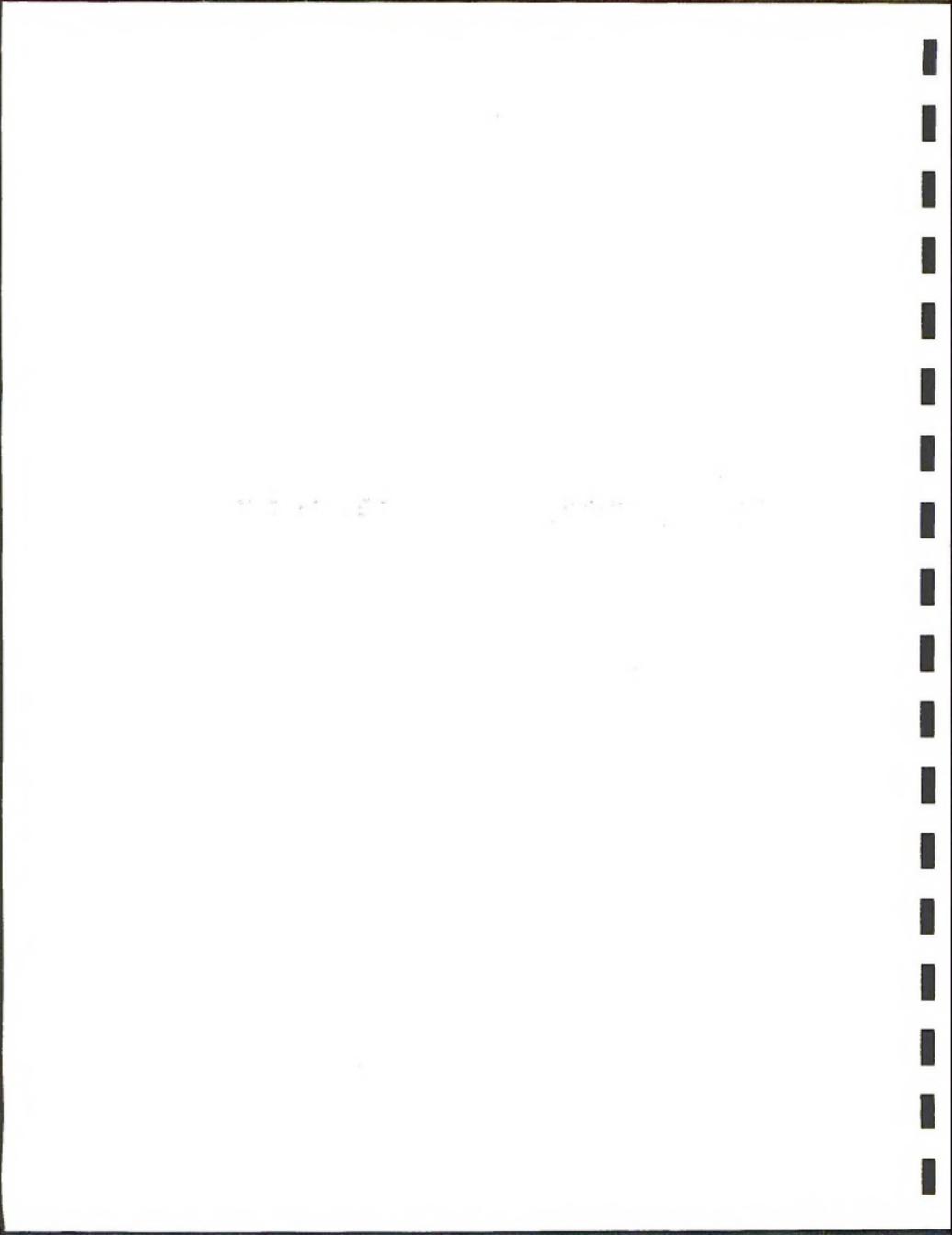




Arizona Cactus Sales-business- depicting Cereus giganteus stock on sale at \$5.50 per foot



Arizona Cactus Sales-business- showing Octillo, barrel, and cholla cacti on sale





Young Saguaro found in the field in the Phoenix, Arizona area



Saguaro cacti growing on a mountain side east of Phoenix,
Arizona near Fountain Hill





Freezing damage on Saguaro cacti -Saguaro National Monument
east of Tucson, Arizona



Close view of freezing damage-Saguaro National Monument-east of
Tucson, Arizona



Young Saguaro (approximately 5-10 yrs old) located at the Saguaro National Monument grounds east of Tucson, Arizona. This young Saguaro is protected by a rodent proof cage designed by Dr. William Steenburgh



Photograph showing a Saguaro stand on the monument

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Photograph showing a healthy stand of Saguaros -Sabino canyon
located northeast of the Saguaro National Monument (East)



Photograph depicting typical understory growth in Saguaro
stands-Sabino canyon (understory contains Cholla and Palo Verde)

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Photograph depicts-understory-growth in typical Saguaro stand.
(understory composition contains Cholla, Palo Verde, and Prickly
Pear)



Photograph shows flower buds and flower of the Saguaro
(Sabino Canyon photograph)

1. The first part of the document is a list of names and addresses of the members of the committee.

2. The second part of the document is a list of names and addresses of the members of the committee.



Photograph shows a Saguaro flower that has fallen and caught within a wound in the Saguaro body. Ants were seen in the flower supposedly carrying off the small tiny black seeds



Photograph depict Saguaro stand at a lower elevation of Mt. Lemmon-North of Sabino canyon

1942

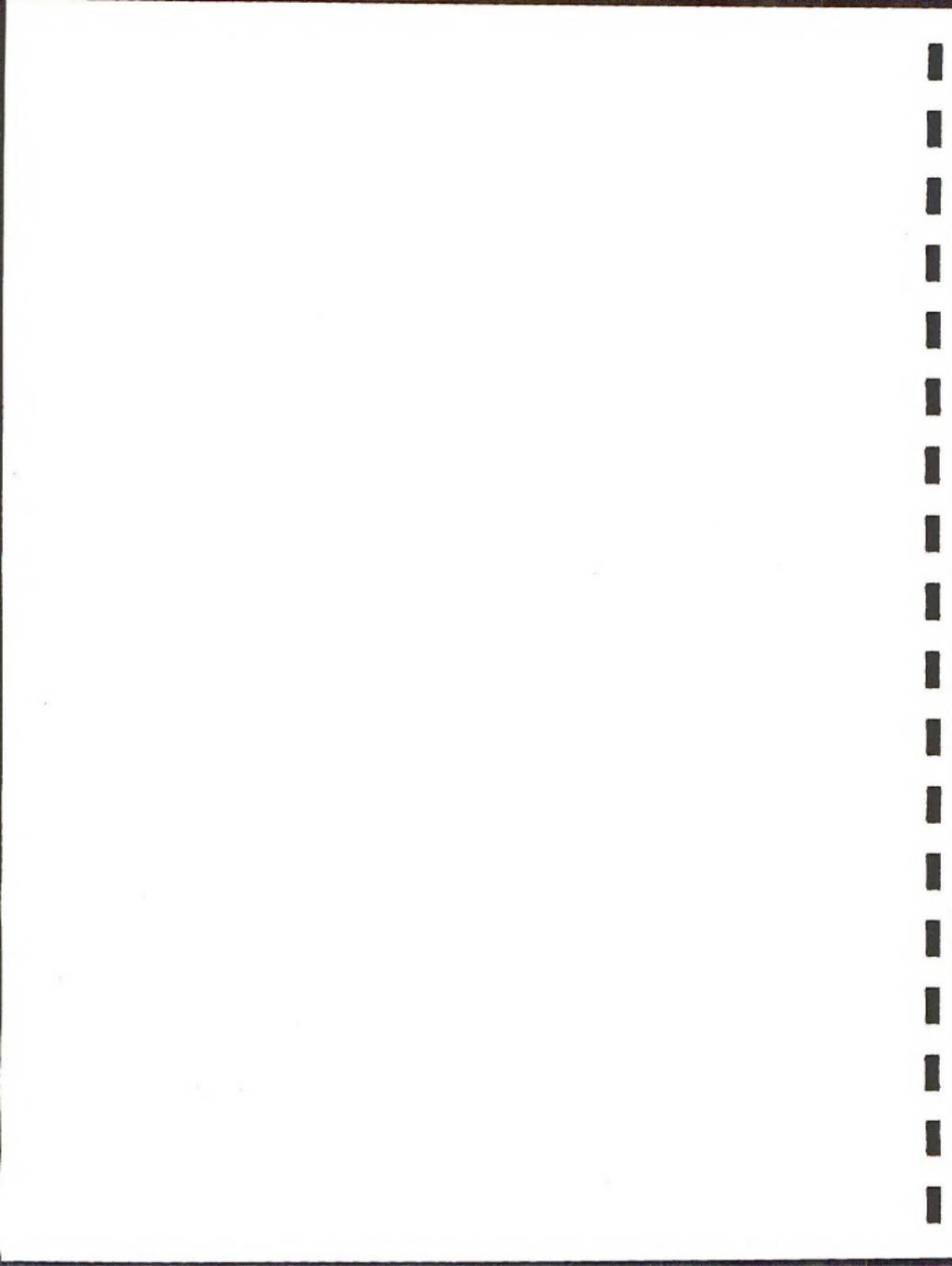
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Photograph depicting a denser stand of Saguaro at a higher elevation of Mt. Lemmon-N. E. of the Saguaro National Monument -East of Tucson, Arizona



Photograph depicts callus tissue that was produced by a Saguaro cactus's hypersensitive reaction to infection by the Cactabrosis larvae connected with Bacterial Necrosis -note striations in longitudinal sections





Photograph shows laboratory germination of Saguaro aged at 2 months old by Dr. Stanley Alcorn-University of Arizona



Saguaro Height Comparison With
Bill Carter (5'7")
Arizona SO





Photograph shows usage of Saguaro Cactus in Home Landscaping



Photograph shows stand of Saguaro Cacti in the Phoenix Area
(Note density)



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