FIELD OBSERVATIONS ON BACTERIAL NECROSIS OF THE GIANT CACTUS

by

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FIELD OBSERVATIONS ON BACTERIAL NECROSIS OF THE GIANT CACTUS 1/

Introduction

The importance, distribution, symptoms, pathological histology, and the causal organism of bacterial necrosis of the giant cactus, Cereus giganteus Englm. (Carnegiea gigantea Britt. & Rose), have been described by Lightle, Standring, and Brown 2/. Additional observations on the occurrence and progress of the disease, caused by Erwinia carnegieana Standring, on a large number of plants, and the distribution and losses caused by it at Saguaro and Organ Pipe Cactus National Monuments (Fig. 1) are presented in this paper.

Experiments

In order to study the disease under field conditions, sample and survey plots were established. The object of the former was to afford facilities for studying the occurrence and progress of bacterial necrosis on a large number of plants under natural conditions; the latter to facilitate the study of (1) the distribution and spread of the necrosis and (2) the losses caused by it in the areas studied.

1/ These observations were made while the writer was employed as Agent by the Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture to investigate possible methods of controlling the bacterial necrosis.

2/ Lightle, Paul C.; Elizabeth T. Standring; and J. G. Brown. A bacterial necrosis of the giant cactus. Phytopath. 32: 303-313. 1942.

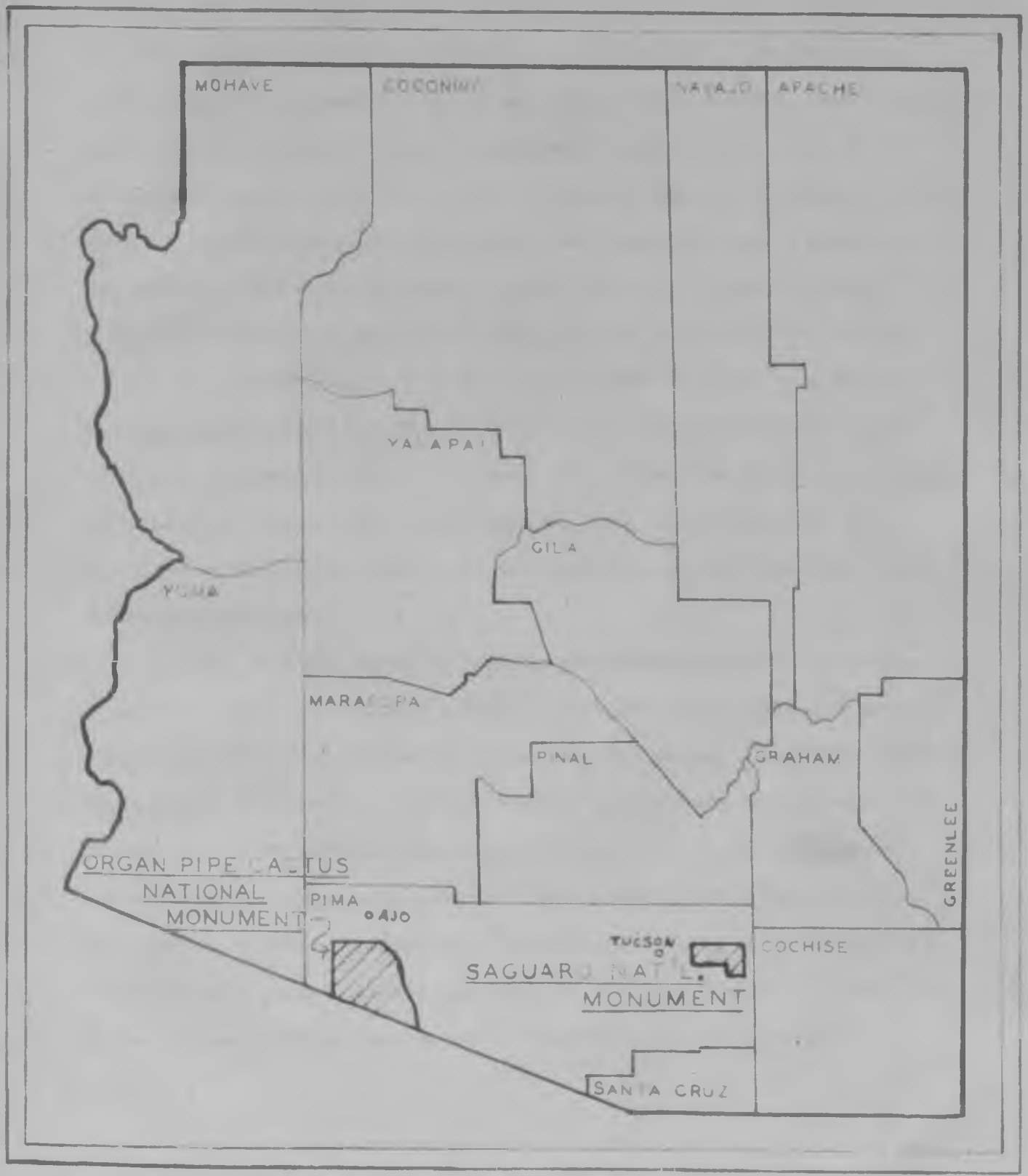

Fig. 1. Outline map of Arizona showing the location of Saguaro and Organ Pipe Cactus National Monuments.

Methods

Six sample plots were established at Saguaro and 3 at Organ Pipe Cactus National Monuments. The former, each 5 acres in area, were designated A to F inclusive. Plots A and B were located in heavy stands of the saguaro cactus; D and E in areas of average saguaro population; F was in a sparse stand; and C was in an area containing many young plants. The selection and study of areas provided a basis for observing the effects of density and age on the intensity and progress of the disease.

A map of each sample plot was made to show the exact positions of the saguaros studied (Fig. 2). Detailed notes were taken on the height; number of branches; presence or absence of disease; the exact size, place, and condition of activity of each necrotic area on the aerial portion of the plant or on exposed roots; and the cause, extent, and location of any mechanical injuries.

Special care was taken to record periodically in detail the degree of activity manifested by the bacterial lesions. Shreve 3/, says when a saguaro is wounded in any manner during the dry season, it quickly recovers by forming a heavy callus over the wounded spot. Those working with the disease have also observed that callusing often occurs in the case of infection by E. carnegieana, the infection being entirely walled off by the plant. In order to determine whether infection in older lesions had been checked it was sometimes necessary to cut away a layer of dried epidermal tissue covering the lesioned area and probe the underlying corky callus.

3/ Britton, N. L. & J. N. Rose. The cactaceae. Descriptions & illustrations of plants of the cactus family. In vol. 2, pp. 164-167. Carnegie Inst. of Wash. Publ. No. 248, 4 vols. 1919-23.

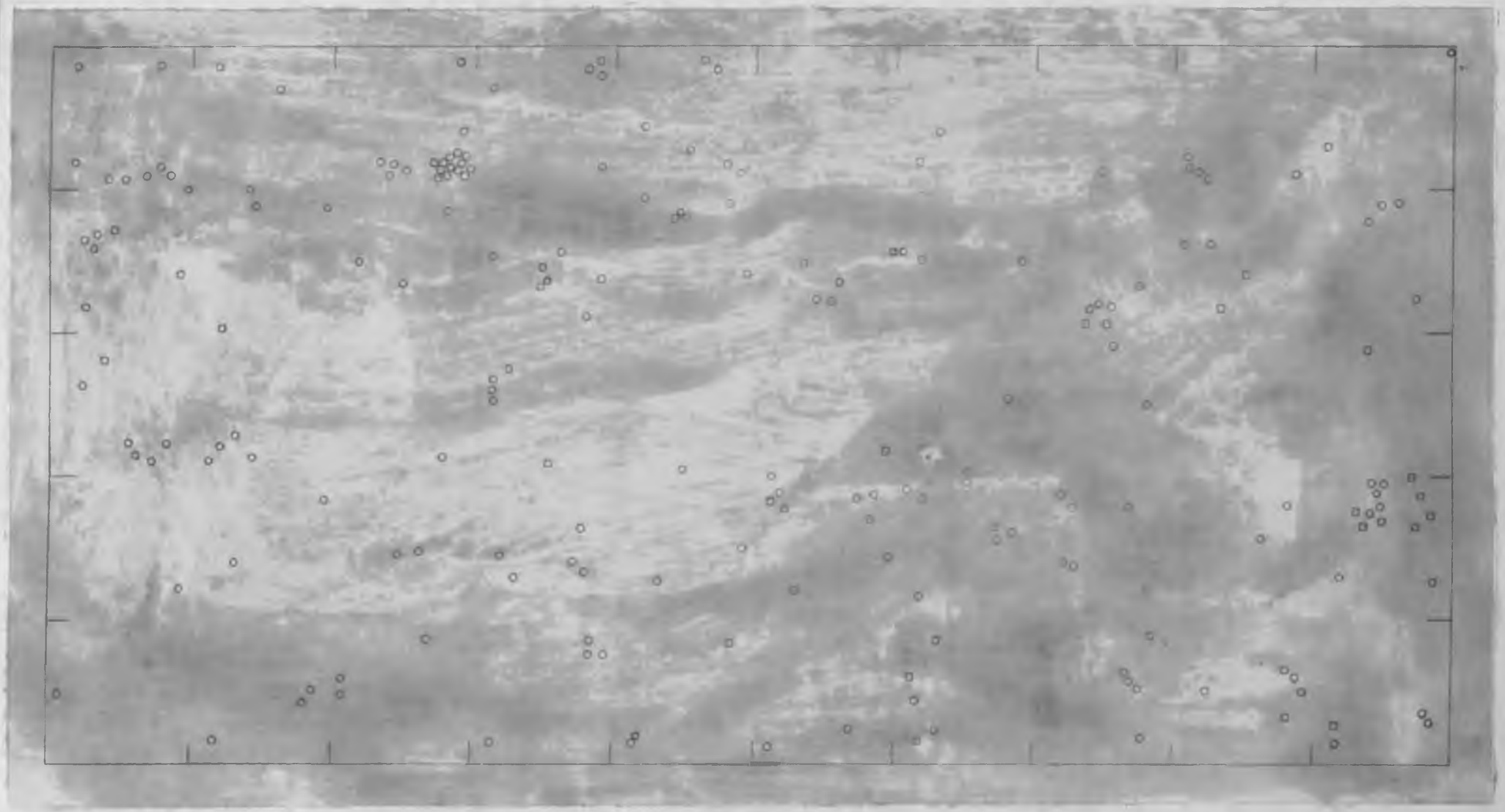

Fig. 2. Map of sample plot "A" showing the location and distribution of the giant cacti on this plot.

The original notes were taken in May, 1941, by the author, with subsequent notes in July and October of the same year; January, May, and July of 1942; and in February and May of 1943 4/. The observation dates were selected to correspond to the different seasons of the year. As they occur in southern Arizona, May and June are hot dry months; July, August, and September are hot and comparatively wet; October, November, and December are cool and dry, while January through April is usually cool and occasionally moist (Chart 1).

The sample plots at Organ Pipe Cactus National Monument, each 0.9 acre in area, were placed in saguaro stands where diseased plants were noted. Maps were made and notes taken as at Saguaro National Monument.

A section of land in the northwest corner of Saguaro National Monument was gridded into 10-acre survey plots by engineering students from the University of Arizona. Each of the plots was divided into four $2\frac{1}{2}$-acre plots and ten of the latter in each quarter-section selected at random for use in the sample survey as shown in Figure 3.

The random $2\frac{1}{2}$-acre plots mentioned above were located by the author in the field by means of a compass and pacing, and a tally made of (1) the total number of giant cacti, (2) the number estimated to have been dead longer than three years (old dead), and (3) the number which were believed to have died in the past three years (recently dead).

Later, a detailed survey of the entire section was made. Every plant was given a number and the condition of its health noted. This survey

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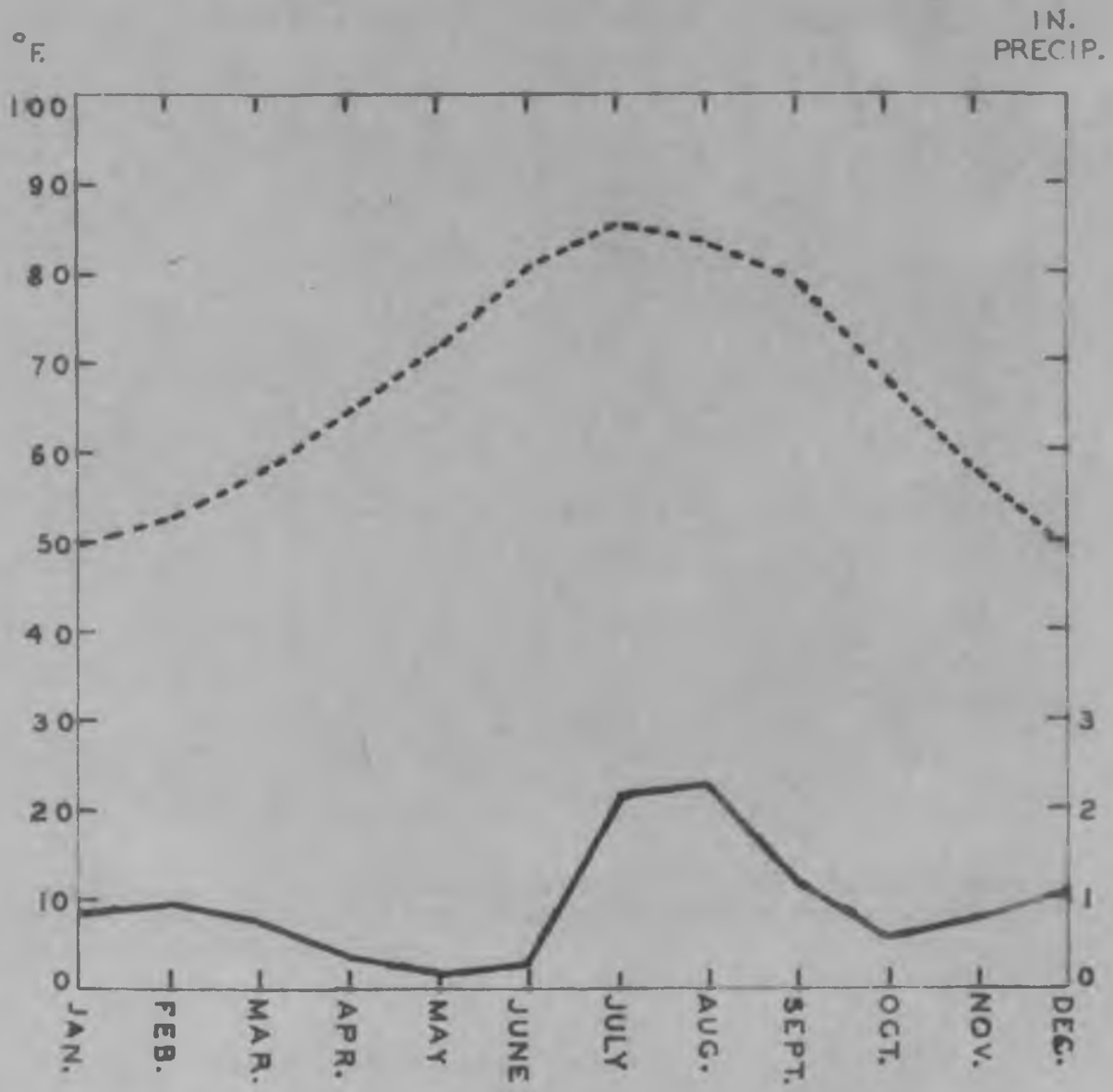
4/ The 1943 observations were made for the author, while he was serving in the U. S. Navy, by Dr. James L. Mielke, Pathologist, Bureau of Plant Industry, Soils and Agricultural Engineering.

CHART I. MEAN MONTHLY PRECIPITATION AND TEMPERATURE.

(1940 BASIS)



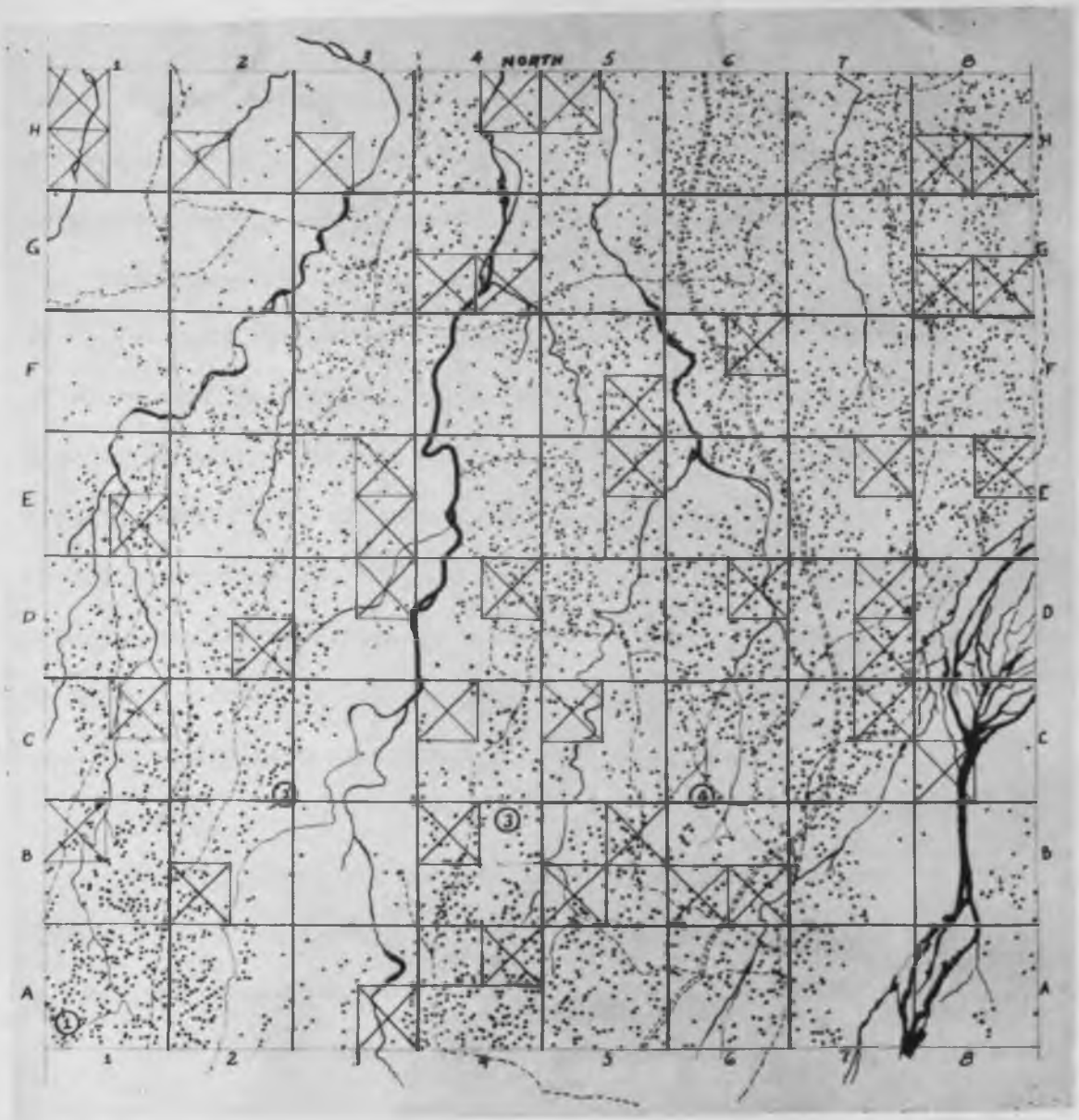


Fig. 3. Map of experimental section (S17, R16E, T14S) at Saguaro National Monument adapted from an aerial photograph made at 5,000 feet by the U. S. Army Air Corps.

Legend:

⊠ - Random 2½-acre survey plot.

. - Saguaro visible on aerial photograph.

(1) - No significance in connection with this paper.

gave a rather striking check on the accuracy of sampling, for there was a difference of only 18 plants or 1/10 of 1% between the estimated number of plants and the actual number found on the section.

At Organ Pipe Cactus National Monument 8 survey plots 1000 x 100 feet were laid out using a compass and tape. These were marked by a line of stakes 200 feet apart from which 50 feet were paced off on either side. A tally by height classes was made of the giant cacti on these areas; height classes I to IV corresponding to heights 0-3, 4-8, 9-16, and over 17 feet respectively. Saguaros in classes I and II were considered to be healthy, unless specifically designated otherwise, while those in III and IV were divided into (1) healthy, (2) old dead (over 3 years), (3) recently dead (less than 3 years), and (4) infected.

Results

The results of the observations on the sample plots are given in Tables 1 to 5 and in Chart 2. The data obtained from the surveys are presented in Tables 6 to 8.

Nearly two-thirds of all the lesions that occur appear between January and June (Table 1), corresponding to the pre-flowering and flowering-fruiting periods of the saguaro. A few more lesions appeared during the latter season than during the former. This indicates that the blossoming time of the cactus may be related to the incidence of infection, but further work will be necessary before the exact nature and extent of the relationship can be understood.

Of all the lesions that start, only a few cause serious injury to the cactus (Table 2). Over a 2-year period, 426 cankers were noted on 171 saguaros out of 953 under observation, but only 15 plants died. Mortality

TABLE 1. Time of year bacterial necrosis lesions originate; based on observations of 5 sample plots (5 acres each):

Plot No.	Observation: May - June	July - Dec.	Jan. - April	Total
A	48	84	74	206
C	45	26	44	115
D	32	13	10	55
E	11	21	2	34
F	7	15	5	27
TOTAL	143	159	135	437
%	32.7	36.4	30.9	100.0

NOTE: Plot B was omitted because other work on this area made comparison impossible.

TABLE 2. Longevity of bacterial necrosis lesions

Number & Date of Observ'n.	Condition of Lesions	Number of lesions at observation 1	2	3	4	5	6	7	8	Total
1	Active	15	13	1	1	1	1	1	0	47
5/41	Inactive	32	34	46	46	46	46	46	47	
2	Active		50	3	3	1	1	1	0	99
7/41	Inactive		49	96	96	98	98	98	99	
3	Active			0	5	5	2	1	0	53
10/41	Inactive			45	48	48	51	52	53	
4	Active				4	0	0	0	0	9
1/42	Inactive				5	9	9	9	9	
5	Active					28	10	6	4	57
5/42	Inactive					29	47	51	53	
6	Active						16	1	1	44
7/42	Inactive						28	43	43	
7	Active							61	3	87
2/43	Inactive							26	84	
8	Active								4	30
5/43	Inactive								26	
										426

in each case was apparently due to the combined effects of a number of lesions. It is felt, however, that some of these outbreaks actually originated from a single internal infection. Some plants have as high as 20 lesions recorded for them without any serious damage being done.

An attempt was made to ascertain whether any particular area of the exposed portion of the saguaro plant was more likely to become infected than another. Only lesions appearing on the main stems of plants over 17 feet tall were counted. Nearly sixty-three per cent of the lesions recorded occurred in the first 10 feet above ground level (Table 3). No reason for this height distribution of cankers was apparent, but the older mature plants were, in general, the plants that were dying, and the data seem to indicate that the older parts of the plant are the parts that are more readily subject to infection by E. carnegieana.

An analysis of data to determine whether lesions occurred on any particular side of the plant with enough regularity to warrant a hypothesis regarding the effects of insolation, temperature, wind, or other climatic factors gave no satisfactory results. There is some variation in the number of lesions at eight major directions (Table 4) but it is felt that this variation is the result of experimental error rather than indicative of a significant relationship between lesions and orientation.

Disease incidence at Organ Pipe Cactus National Monument (Table 5) is less than at Saguaro National Monument.

Chart 2 presents data taken from weather records at the University of Arizona over a 3-year period from 1941 to 1943. No correlation is apparent between incidence of disease and either temperature or precipitation. The seasonal variations in infection are clearly noticeable but the predominance of spring infections is evident.

TABLE 3. Height at which bacterial necrosis lesions occur on plants over 17' tall.

Height Feet	Number of lesions by Plots A*	C	D	E	F	Total	
1	2	3	1	0	0	6	
2	8	5	8	7	3	31	
3	8	2	3	0	3	16	
4	18	2	6	4	4	34	
5	4	2	3	2	1	12	
6	9	0	2	2	3	16	
7	6	2	5	1	2	16	
8	10	3	4	3	0	20	
9	8	1	2	3	1	15	
10	19	3	1	2	0	25	- 191 or 62.6%
11	3	3	3	2	1	12	
12	7	6	4	0	2	19	
13	7	1	1	1	0	10	
14	12	1	3	1	1	18	
15	12	0	2	0	1	15	
16	3	0	0	0	0	3	
17	1	1	0	0	0	2	
18	6	0	1	1	1	9	
19	2	0	0	0	0	2	
20	4	0	1	1	3	9	
21	4	1	0	1	0	6	
22	3	0	0	0	1	4	
23	2	0	0	0	0	2	
24	2	0	1	0	0	3	- 114 or 37.4%
TOTAL	160	36	51	31	27	305	or 100%

* - Plot symbol.

NOTE: Plot B was omitted because other work on this area made comparison impossible.

TABLE 4. Orientation of bacterial necrosis lesions based on observations of 5 sample plots (5 acres each):

Orientation	Number of lesions by plots: A*	C	D	E	F	Total
N	28	22	10	6	6	72
NE	10	17	4	1	2	34
E	42	11	9	4	4	70
SE	12	3	1	4	0	20
S	24	11	5	4	4	48
SW	21	9	7	4	1	42
W	36	24	8	8	1	77
NW	20	15	9	2	9	55
TOTAL	193	112	53	33	27	418

* - Plot symbol.

NOTE: Plot B was omitted because other work on this area made comparison impossible.

TABLE 5. Disease incidence at Organ Pipe Cactus National Monument.

Plot Number	Total Cacti	Dead		Dying		Diseased	
		No.	%	No.	%	No.	%
III	20	6	30.0	0	0.0	0	0.0
IV	45	0	0.0	0	0.0	1	2.2
V	72	6	8.3	0	0.0	0	0.0
Total	137	12	8.8	0	0.0	1	0.7

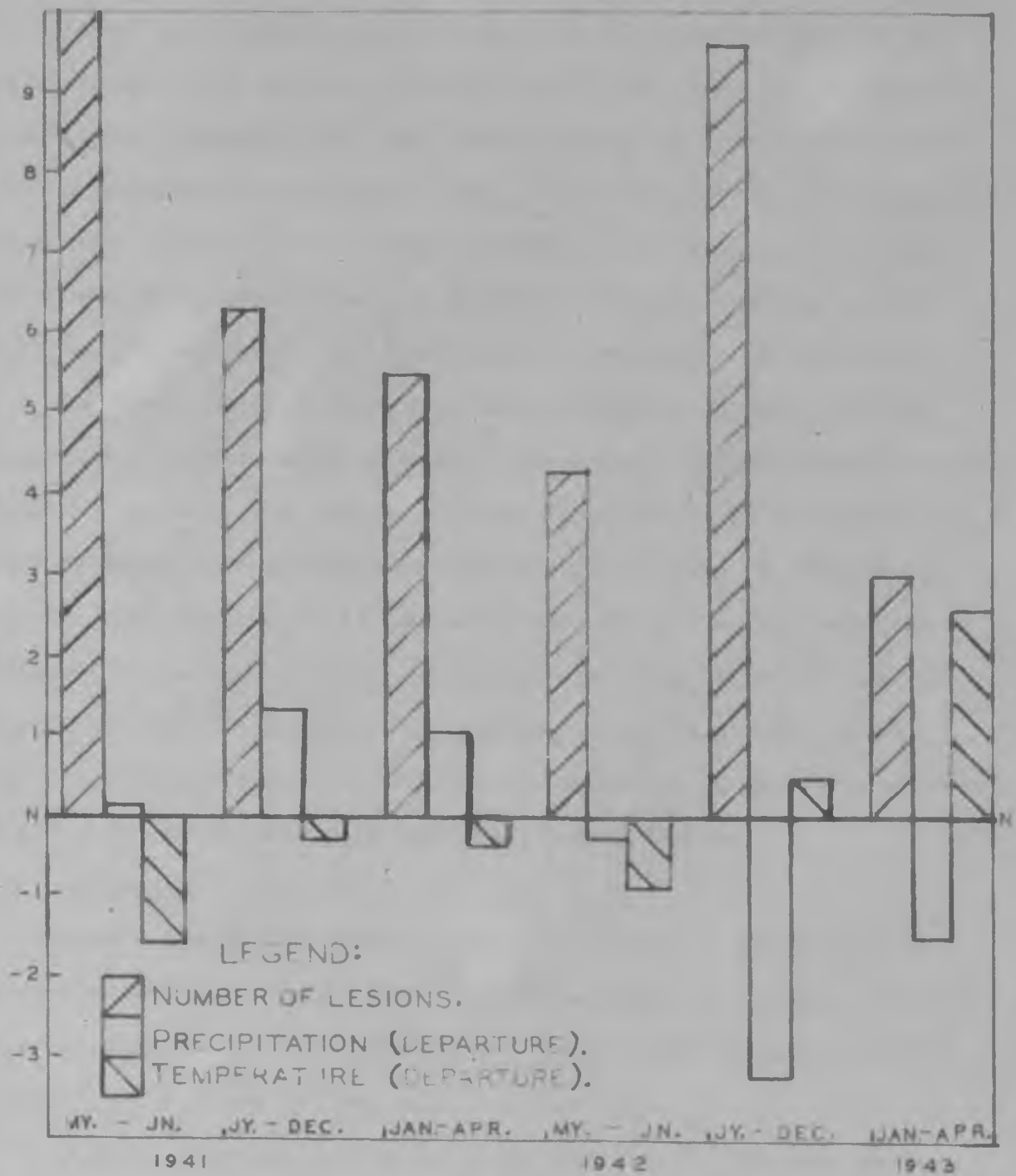


CHART 2. OCCURRENCE OF LESIONS BY OBSERVATION PERIOD AND DEPARTURE FROM NORMAL TEMPERATURE AND PRECIPITATION.

At Saguaro National Monument mortality is about 8 per cent (Tables 6 & 7) over an estimated 3-year period (or 2.67 per cent annually), which is much higher than would be expected from a plant whose life is considered by some botanists 5/ to span several centuries. The amount of natural reproduction in this area is small, and if the present rate of loss is continued, only a few decades will pass before the dense forest of giant cacti will be devastated and in a period of 50 years, scarcely a giant will be left standing. Such destruction has been noted in other areas.

The survey plots at Organ Pipe Cactus National Monument, like the sample areas, were located in saguaro stands where the disease was present. While the percentage of dead or diseased plants (Table 8) is similar to that at Saguaro National Monument (Table 7), the number of young plants at the former location is of such magnitude that little importance can be attached to the loss. General surveys on Organ Pipe Cactus National Monument also show the disease to be confined to small areas whereas at Saguaro National Monument it is heavy throughout the entire stand of older giant cacti but is heavier in some areas than in others.

Discussion

Saguaro plants have shown a remarkable ability to wall off, by the formation of callus tissue, infections caused by E. carnegieana. Table 2 clearly shows that this is true for out of 426 lesions appearing on 171 plants, over a 2 year period, only 15 plants died.

Lightle, Standring, and Brown 6/ say that the necrosis may start

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5/ Shreve, Forrest. The rate of establishment of the giant cactus. Plant World. 13: 235-240. 1910.

6/ Op. Cit. page 307.

TABLE 6. Sample survey of bacterial necrosis at Saguaro National Monument.

10-acre Field 1/ Plot No.	Quarter of Plot	Number of plants: Dead or diseased 2/: Old	Recent	Healthy
H8	SE	0	12	50
H8	SW	0	5	77
H5	NW	7	6	27
G8	SW	3	1	84
G8	SE	5	6	64
F6	NE	1	3	66
F5	SE	9	8	102
E5	NE	19	19	211
E7	NE	4	5	65
E8	NE	2	7	55
H4	NE	0	0	16
H3	SW	0	0	2
H2	SW	0	0	5
H1	NW	0	0	1
H1	SW	4	3	7
G4	SW	11	4	38
G4	SE	0	2	7
E3	NE	2	0	18
E3	SE	1	1	6
E1	SE	4	3	34
D4	NE	5	2	40
D3	NE	1	2	9
D2	SE	7	1	48
C1	NE	3	9	61
C4	NW	2	1	25
B4	NW	8	7	54
B2	SW	1	4	101
B1	NW	0	1	20
A3	SE	0	3	15
A4	NE	6	15	105
D7	NE	6	12	53
D7	SE	1	5	39
D6	NE	5	4	66
C5	NW	4	2	39
C7	NE	1	3	54
C8	SW	2	0	6
B5	NE	1	12	62
B5	SW	1	3	75
B6	SW	4	3	61
B6	SE	4	4	50
TOTAL		134	178	1,918
Per cent		6.0	8.0	86.0

1/ Field plot numbers refer to rows and tiers in Figure 3.

2/ Old - plants which had been dead longer than 3 years.
Recent - badly diseased plants and dead plants which presumably died within the past 3 years.

TABLE 7. Bacterial necrosis survey at Saguaro National Monument.

Field * Plot No.	Healthy	Diseased	Dead	Field * Plot No.	Healthy	Diseased	Dead
A-1	325	29	30	E-1	126	4	10
A-2	209	14	27	E-2	207	5	36
A-3	140	6	10	E-3	110	2	17
A-4	382	33	90	E-4	188	5	20
A-5	302	12	37	E-5	367	18	52
A-6	293	8	53	E-6	316	23	52
A-7	71	4	40	E-7	247	26	41
A-8	48	2	17	E-8	197	6	27
B-1	228	18	33	F-1	42	3	4
B-2	119	10	43	F-2	111	4	9
B-3	31	1	12	F-3	246	13	35
B-4	277	27	78	F-4	151	3	22
B-5	293	9	55	F-5	340	9	37
B-6	199	5	50	F-6	282	14	29
B-7	148	7	26	F-7	240	13	34
B-8	57	5	21	F-8	281	6	16
C-1	171	10	18	G-1	29	0	3
C-2	175	11	38	G-2	32	1	3
C-3	66	4	26	G-3	131	7	17
C-4	165	4	18	G-4	96	8	21
C-5	257	16	24	G-5	266	20	30
C-6	350	21	39	G-6	335	14	17
C-7	291	23	26	G-7	202	9	31
C-8	45	1	18	G-8	303	11	20
D-1	208	12	25	H-1	19	1	10
D-2	179	10	19	H-2	21	2	4
D-3	74	3	20	H-3	24	0	3
D-4	125	6	34	H-4	105	2	16
D-5	319	22	45	H-5	232	6	31
D-6	315	13	35	H-6	498	22	21
D-7	177	20	47	H-7	279	8	23
D-8	24	0	7	H-8	255	2	22
TOTALS	6061	356	1061	TOTALS	6278	267	713

* Field plot numbers refer to rows and tiers in Figure 3.

TABLE 8. Bacterial necrosis survey at Organ Pipe Cactus National Monument.

Plot No.	Total Cacti	Class III						Class IV					
		#OD[1]	%OD	#RD[2]	%RD	#I[3]	% I	#OD	%OD	#RD	%RD	# I	% I
I	23	3	13.0	0	0.0	0	0.0	1	4.3	0	0.0	0	0.0
II	70	3	4.3	0	0.0	0	0.0	3	4.3	0	0.0	3	4.3
III	92	5	5.4	0	0.0	0	0.0	4	4.3	3	3.2	0	0.0
IV	39	3	7.7	1	2.6	0	0.0	0	0.0	1	2.6	0	0.0
V	50	2	4.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
VI	51	4	7.8	0	0.0	0	0.0	4	7.8	1	1.9	0	0.0
VII	52	6	11.5	0	0.0	0	0.0	1	1.9	1	1.9	0	0.0
VIII	66	1	1.5	0	0.0	0	0.0	2	3.0	2	3.0	0	0.0
TOTAL	443	27	6.1	3	0.7	0	0.0	15	3.4	8	1.4	3	1.1

1. OD - Old dead (plants dead over three years).
2. RD - Recently dead.
3. I - Infected.

SUMMARY: Of the 443 cacti, 33.6% were in Class I, 16.3% were in Class II, 19.6% were in Class III, and 30.5% were in Class IV. Healthy plants totaled 67.3%.

any place on the main stem or branches of the saguaro, but indicate that it is common for lesions to occur near the base of the plant. Table 3 affirms this, for nearly two-thirds of all lesions noted on plants over 17 feet tall appeared in the lower 10 feet, but some cankers were recorded as high as 24 feet above the ground.

Conclusions

The following conclusions have been drawn from the data presented:

(1) Visual symptoms of the disease appear more frequently during the period from January to June than from July to December, with more lesions occurring between May and June than between January and April.

(2) Only a few of the many lesions appearing are lethal, the others being checked by the formation of callus tissue by the plant.

(3) Lesions are more numerous on the lower or older portions of the plant.

(4) On the basis of present information, insolation, temperature, wind or other climatic factors have no direct effect on the seasonal occurrence of lesions.

(5) If the disease continues to kill plants at Saguaro National Monument at the present rate, the stand will be greatly reduced within a few decades.

Summary

Data are presented showing the time of year bacterial necrosis lesions originate, the longevity, part of the plant usually affected, and the orientation of such lesions together with general data on the prevalence of the necrosis, and the damage that the disease is causing on two National Monuments.

Acknowledgements

The writer wishes to acknowledge his indebtedness to Dr. J. G. Brown for his guidance and criticisms during the course of this work and to Dr. Lake S. Gill for his help in developing this project. To Dr. R. B. Streets and Dr. Paul D. Keener, the writer is also indebted for a critical reading of the manuscript.