

A SURVEY OF THE HAY FEVER PLANTS AND IMPORTANT ATMOSPHERIC ALLERGENS IN THE PHOENIX, ARIZONA, METROPOLITAN AREA

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INTRODUCTION

THE first extensive publication concerning pollinosis in Arizona was that by Watson and Kibler¹ in which an attempt was made to list all the plants thought to be capable of causing hay fever in the Southwest. Anemophilous plants were then classified as to their importance on the basis of field and clinical observations. Following this, E. W. Phillips, a local physician, became the leading investigator of the pollen allergens in the Phoenix metropolitan area. He tested his patients intradermally with pollen extracts made from naturally ripened pollen collected in the Phoenix area. By correlating his clinical records with concise field observations of pollinating plants, he assembled data for numerous publications²⁻¹⁰ concerning the treatment of pollinosis and the seasonal occurrence of specific pollen allergens.

In 1944 Randolph and McNeil¹¹ published the first and only atmospheric study that has been made of pollen grains in the Phoenix area over an extended period of time. Their investigations were made from 1934 through 1936. Due to the standardization of the technique for atmospheric pollen testing in 1946 by the Pollen Survey Committee of the Research Council of the American Academy of Allergy,¹²⁻¹³ the concentrations of atmospheric pollen grains found in the Randolph and McNeil study cannot be compared with observations presented in this article. In reporting their investigation, Randolph and McNeil state: "The slides are mounted at a 45 degree angle on weather vane arrangement, protecting them from rain but allowing full exposure to the air. Because the slide automatically faces into the air currents, there is greater volume of pollen deposited on windy days than would be with the slide lying flat on the window ledge." Their data, however, can be used in a comparison of the general seasonal pollen occurrence.

The purpose of this article is twofold. First of all, it is my intention to present a survey of the plants considered to be responsible for inhalant allergies in the Phoenix, Arizona, metropolitan area. The second objective is to supply data and information concerning the kind, concentration, and seasonal

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occurrence of the atmospheric pollen grains and fungous spores found during a one-year investigation conducted from June 1, 1957, through May 31, 1958, in Phoenix and Tempe, Arizona. Presentations of this nature are common, for nearly every heavily populated community in the United States has information concerning its atmospheric allergens. The Phoenix area, however, has not had the advantage of a complete aerobiologic survey of allergenic pollen grains and fungous spores. Considering that this region is the population center of Arizona, the need and importance of atmospheric allergen data become evident.

MATERIALS AND METHODS

A botanical survey was conducted at the outset of this study to ascertain which plants, capable of causing pollinosis, could be found in the Phoenix area. All the anemophilous plants were considered along with a few entomophilous plants known to produce pollen in such quantities that many grains become air-borne. Concurrently, pollen samples were collected from the different plant species, and permanent microscope slides were prepared by mounting the pollen grains in glycerin jelly stained with basic fuchsin. Many different fungous spores were similarly prepared. Photomicrographs and camera lucida drawings were made of these pollen grains and fungous spores at a magnification of 970 $\times$ obtained with a monocular Bausch & Lomb microscope.

The next step in this investigation was the selection of two collecting stations for purposes of exposing prepared slides to the atmosphere. One of the sites chosen for a station was located in the Goodwin Stadium on the campus of Arizona State University in Tempe, Arizona. The standard Durham gravity sampling device was placed on top of the press box at a point free from all obstructions, approximately 50 feet above the ground level. The second station was located on the administration building at Phoenix Union High School in downtown Phoenix. The sampling device was placed at a point about 40 feet from ground level on the edge of the roof. It was relatively free from obstruction except for a slightly higher section of the roof about 30 feet northeast of the sampler.

The atmospheric survey of the pollen grains and fungous spores at the two stations previously designated was obtained by the gravity method described by Durham¹⁴ and approved by the American Academy of Allergy.¹²⁻¹³ Slides coated with a thin layer of glycerin jelly stained with basic fuchsin dye were placed, face up, on the horizontal platform in the standard air-sampling device. Slides were exposed for forty-eight hours from 8 A.M. Monday to 8 A.M. Wednesday, from 8 A.M. Wednesday to 8 A.M. Friday, and for a seventy-two-hour period from 8 A.M. Friday to 8 A.M. Monday. All readings from these slides were converted to represent twenty-four-hour averages.

The slides were prepared for microscopic examination by placing a 4.84 sq. cm. cover slip on the glycerin jelly that had been softened by heat. The slides were then examined under oil immersion with a monocular microscope,

and identification was made by comparing the pollen grains and spores with the permanent mounts, photomicrographs, and camera lucida drawings. The counts were recorded under low-power magnification, using a 10× objective and 15× ocular. With this magnification, the entire area under the cover slip can be counted in twelve horizontal sweeps. Every other sweep was counted, however, for a total of six horizontal sweeps or an area of 2.42 sq. cm. Each total count was then divided by 2.42, which gave the average number of pollen grains or fungous spores per square centimeter. Finally, an interpolation was made, converting the number of pollen grains per square centimeter to the number

TABLE I. CONVERSION FACTORS

NAME OF LOCAL POLLEN (SCIENTIFIC AND COMMON)	NAME OF EXPERIMENTAL POLLEN* (SCIENTIFIC AND COMMON)	AVERAGE DIAMETER OF LOCAL POLLEN (MICRONS)	AVERAGE DIAMETER OF EXPERI- MENTAL POLLEN (MICRONS)	CONVERSION FACTORS	
				LOCAL POLLEN	EXPERI- MENTAL POLLEN
<i>Cynodon dactylon</i> (Bermuda grass)	(<i>Capriola</i>) <i>Cynodon dactylon</i> (Bermuda grass)	30.0	28.5	1.55	1.71
<i>Sorghum halepense</i> (Johnson grass)	(<i>Capriola</i>) <i>Cynodon dactylon</i> (Bermuda grass)	38.0	28.5	0.97	1.71
<i>Amaranthus palmeri</i> (careless weed)	<i>Amaranthus palmeri</i> (careless weed)	28.0	25.8	1.48	1.71
<i>Atriplex</i> species (saltbush)	<i>Salsola kali</i> (<i>pestifer</i>) (Russian thistle)	22.0	23.6	1.98	1.71
<i>Beta vulgaris</i> (sugar beet)	<i>Salsola kali</i> (<i>pestifer</i>) (Russian thistle)	22.0	23.6	1.98	1.71
<i>Chenopodium</i> species and miscellaneous chenopods	<i>Salsola kali</i> (<i>pestifer</i>) (Russian thistle)	24.0	23.6	1.65	1.71
<i>Salsola kali</i> (Russian thistle)	<i>Salsola kali</i> (<i>pestifer</i>) (Russian thistle)	26.0	23.6	1.41	1.71
<i>Sarcobatus vermiculatus</i> (greasewood)	<i>Salsola kali</i> (<i>pestifer</i>) (Russian thistle)	24.0	23.6	1.65	1.71
<i>Dicoria canescens</i> (dicoria)	<i>Franseria acanthicarpa</i> (Bur-ragweed)	22.0	22.0	3.16	3.16
<i>Franseria</i> species (false ragweed)	<i>Franseria acanthicarpa</i> (Bur-ragweed)	22.0	22.0	3.16	3.16
<i>Hymenoclea</i> species (burrobrush)	<i>Ambrosia elatior</i> (short ragweed)	20.0	20.0	3.60	3.60
<i>Plantago</i> species (plantain)	<i>Plantago lanceolata</i> (English plantain)	26.0	27.5	2.38	2.13
<i>Rumex</i> species (curly dock and canaigre)	<i>Rumex acetosella</i> (red sorrel)	30.0	21.5	1.75	3.40
<i>Cupressus</i> and <i>Juniperus</i> (cypress and juniper)	<i>Juniperus sabinoides</i> (mountain cedar)	27.0	22.8	1.96	2.75
<i>Fraxinus velutina</i> (Arizona ash)	<i>Fraxinus americana</i> (ash)	23.0	27.1	2.90	2.09
<i>Olea europaea</i> (olive)	<i>Fraxinus americana</i> (ash)	21.0	27.1	3.48	2.09
<i>Populus fremontii</i> (cottonwood)	<i>Populus virginiana</i> (cottonwood)	30.0	30.0	2.09	2.09
<i>Morus</i> species (mulberry)	<i>Ulmus americana</i> (elm)	20.0	31.2	3.70	1.56
<i>Ulmus</i> species (elm)	<i>Ulmus americana</i> (elm)	31.0	31.2	1.58	1.56

*Experimental pollen used by Durham.¹⁴

of grains per cubic yard of air. This was attained by using the standard conversion factors suggested by Durham,¹⁴ who derived his data from experimental rates of fall for pollen grains as compared with pollen grains of *Ambrosia*

elator L., the short ragweed. This conversion uses the factor 3.6 for short ragweed as a pivot for establishing conversion factors for other types of pollen. The rate of fall of a given pollen grain is divided into 3.6, and then the calculated factor is multiplied by the number of grains per centimeter on a slide. The product of this represents the number of pollen grains per cubic yard of air. Due to the difference in size of the local pollen grains as compared to the similar experimental pollen grains used by Durham, many of the experimental conversion factors had to be adjusted to local factors. This was accomplished by using the following formula as recommended by Durham¹⁴:

$$\text{Conversion factor for local pollen grain} = \frac{(\text{Diameter of experimental grain})^2 \left(\frac{\text{Conversion factor}}{\text{of experimental grain}} \right)}{(\text{Diameter of similar local grain})^2}$$

In comparing "similar" pollen grains it was necessary, in many cases, to relate the size of grains from plants of the same family, rather than from the same genus, because the number of different local species being reported was greater than the number of experimental species previously determined. In calculating the conversion factor of pollen of the *Morus* species, however, a factor of a closely similar experimental pollen was not available; therefore, the comparison was made with pollen of *Ulmus* species, another plant of the order Utricales.

Table I gives the experimental conversion factors as established by Durham¹⁴ and the calculated local factors.

Conversion factors could not be established for some pollen grains or for all the fungous spores. These counts were reported as number per square centimeter on a slide.

A final step in this investigation was the compilation of climatologic data for the Phoenix area and its comparison with the concentrations of atmospheric allergens.

RESULTS

Botanical Survey.—The following is a list of the important plants found in the metropolitan Phoenix area capable of causing pollinosis and the months in which they pollinate. All common names were taken from the list prepared by the Herbarium Committee of the American Academy of Allergy with the exception of the names indicated by asterisks, which were taken from *Arizona Flora* by Kearney and Peebles.¹⁵

<i>Scientific Name</i>	<i>Common Name</i>	<i>Time of Pollination (Inclusive)</i>	<i>Prevalence†</i>
AMARANTHACEAE			
<i>Amaranthus palmeri</i>	Careless weed*	May-November	++
CHENOPODIACEAE			
<i>Allenrolfea occidentalis</i>	Pickleweed*	August-November	—
<i>Atriplex canescens</i>	Wingscale saltbush*	July-October	—
<i>Atriplex elegans</i>	Wheelscale saltbush*	April-July	+
<i>Atriplex lentiformis</i>	Lens-scale saltbush	July-October	+
<i>Atriplex polycarpa</i>	Allscale saltbush	July-October	—
<i>Atriplex wrightii</i>	Annual saltbush	June-October	+

<i>Bassia hyssopifolia</i>	Smotherweed*	August-October	+
<i>Beta vulgaris</i>	Sugar beet	April-June	+
<i>Chenopodium album</i>	Lamb's-quarter	March, April	-
<i>Chenopodium ambrosioides</i>	Wormseed goosefoot*	July-September	-
<i>Chenopodium murale</i>	Nettle-leaf goosefoot	December-April	+
<i>Chenopodium pratericola</i>	Goosefoot*	March, April	-
<i>Salsoia kali</i>	Russian thistle	May-November	++
<i>Sarcobatus vermiculatus</i>	Greasewood*	July-September	-
<i>Suaeda torreyana</i>	Seepweed*	July, August	+
COMPOSITAE			
<i>Dicoria canescens</i>	Dicoria	August-October	-
<i>Franseria ambrosioides</i>	Canyon ragweed	March, April	+
<i>Franseria confertiflora</i>	Slender ragweed	June-October	+
<i>Franseria deltoidea</i>	Rabbit bush	February-May	++
<i>Franseria dumosa</i>	Desert ragweed	March-May, October, November	-
<i>Hymenoclea monogyra</i>	Burrobrush (jecote)	September-November	-
<i>Hymenoclea salsola</i>	White burrobrush	April-June	+
EUPHORBIACEAE			
<i>Ricinus communis</i>	Castor bean	April-November	+
GRAMINEAE			
<i>Cynodon dactylon</i>	Bermuda grass	February-November	++
<i>Sorghum halepense</i>	Johnson grass	March-October	++
PLANTAGINACEAE			
<i>Plantago insularis</i>	Indian wheat*	February-May	+
POLYGONACEAE			
<i>Rumex crispus</i>	Curly dock*	April, May	+
<i>Rumex hymenosepalus</i>	Canaigre*	April, May	-
MISCELLANEOUS TREES			
<i>Cupressus</i> species	Cypress	December-May	+
<i>Fraxinus velutina</i>	Arizona ash	February-April	+
<i>Juniperus</i> species	Juniper	October-January	-
<i>Morus</i> species	Mulberry	March-May	++
<i>Olea europaea</i>	Olive	April, May	++
<i>Populus fremontii</i>	Cottonwood	January-March	++
<i>Ulmus</i> species	Elm	February, March	-

*Names taken from Kearney and Peebles: *Arizona Flora*.¹⁵

†Symbols denoting relative abundance of plants: ++ = Abundant. + = Common. - = Sparse.

Listed below are the important fungi found in the Phoenix area and the months in which they sporulate.

Scientific Name	Common Name	Time of Sporulation (Inclusive)
<i>Acrothecium</i> species	None	September-November
<i>Alternaria</i> species	None	January-December
<i>Helminthosporium</i> species	None	January-December
<i>Homobasidiomycetes</i>	Mushrooms	September-December
<i>Homodendrum</i> species	None	February-December
<i>Sphacelotheca holci</i>	Johnson grass smut	January-December
<i>Stemphylium</i> species	None	January-December
<i>Trichageum</i> species	None	March-May, September, October
Uredinales	Rusts	January-December
<i>Ustilago cynodontis</i>	Bermuda grass smut	February-November

A number of anemophilous plants, especially grasses, were not listed as important allergenic contributors. These plants are either too sparse or they have been shown to be insignificant in the atmospheric study. Some of these plants, however, may cause pollinosis in a susceptible person if there are large

TABLE II. MONTHLY AND YEARLY TOTALS
TEMPE, ARIZONA

SCIENTIFIC NAME	1957						1958						TOTAL	PER CENT	
	JUNE	JULY	AU- GUST	SEP- TEM- BER	OCTOBER	NOVEM- BER	DECEM- BER	JANU- ARY	FEBRU- ARY	MARCH	APRIL	MAY			
<i>Pollen Grains per Cubic Yard of Air</i>															
<i>Amaranthus palmeri</i>	3.2	13.9	77.1	283.5	63.0	2.4							9.6	452.7	4.5
<i>Atriplex</i> species	7.4	21.0	57.2	102.6	15.5	0.8						1.5	2.8	208.8	2.0
<i>Beta vulgaris</i>	12.2											1.6	34.5	48.3	0.5
<i>Chenopodium</i> species and miscellaneous chenopods	2.1	0.9	16.8	24.9	4.0	6.8	1.6	2.4		4.3	8.2	0.8	0.8	55.2	0.5
<i>Salsola kali</i>				6.3	3.6	1.2							6.6	37.5	0.4
<i>Sarcobatus</i> <i>vermiculatus</i>		2.7	4.0	5.4										12.1	0.1
<i>Dicoria canescens</i>				0.6	19.1	0.8								20.5	0.2
<i>Franseria</i> species		2.8	3.2	29.3	53.1	14.3			23.7	261.7	1,066.0		139.6	1,593.7	15.9
<i>Hymenoclea</i> species				8.0	23.8						100.6		48.5	180.9	1.8
<i>Cynodon dactylon</i>	54.9	67.1	32.5	32.0	25.8	5.1	1.3		5.1	28.0	131.1	171.3	5.6	554.2	5.5
<i>Sorghum halepense</i>	3.3	6.3	4.4	24.6	3.9					5.6	13.4		5.6	67.1	0.7
<i>Plantago</i> species										22.0	54.1			76.1	0.8
<i>Rumex</i> species										0.7	4.6		0.6	5.9	0.06
<i>Cupressus-Juniperus</i>			5.9	5.9	3.2	51.2	329.7	288.7	128.3	50.7	175.7		47.4	1,080.8	10.7
<i>Fraginus velutina</i>									77.2	183.2	10.8			271.2	2.7
<i>Morus</i> species									3.0	3,674.0	1,068.6		24.0	4,769.6	47.2
<i>Olea europaea</i>										6.6	107.4		218.1	332.1	3.3
<i>Populus fremontii</i>								31.8	229.3	35.8	0.9			297.8	2.9
<i>Ulmus</i> species										41.7	0.6			42.3	0.4
<i>Pollen Grains per Square Centimeter per Slide</i>															
<i>Pinus</i> species						1.2			1.6	7.1			23.1	33.0	
<i>Prosopis juliflora</i>											23.2			23.2	
<i>Ricinus communis</i>		0.4		5.1	3.0	12.4	3.6				2.8		5.7	33.8	
Miscellaneous grass	8.2	7.9	7.4	1.1	1.6				5.2	10.7	5.6			47.7	
Miscellaneous	3.5	2.5	0.4	1.2	1.0	15.2	9.2	12.3	10.1	8.8	21.3		5.3	90.8	

Pollen index¹⁷ = $\frac{1594}{200}$ (season total) + $20 \left(\frac{\text{number of days with count over } 25}{85} \right)$ + 28.7 (highest single count) = 28.7.

isolated stands near the person's home or place of employment. The following is a list of these locally important contributors.

<i>Scientific Name</i>	<i>Common Name</i>	<i>Time of Pollination*</i>
AMARANTHACEAE		
<i>Amaranthus fimbriatus</i>	Pigweed	June-September
<i>Amaranthus graecizans</i>	Tumbleweed	June-September
GRAMINEAE		
<i>Bromus</i> species	Brome grass	March-October
<i>Distichlis stricta</i>	Salt grass	March-October
<i>Phalaris</i> species	Canary grass	March-October
<i>Poa</i> species	Bluegrass	March-October
<i>Sorghum sudanensis</i>	Sudan grass	March-October
POLYGONACEAE		
<i>Rumex conglomeratus</i>	Clustered dock	April, May
MISCELLANEOUS TREES		
<i>Acacia farnesiana</i>	Sweet acacia	March-May
<i>Carya pecan</i>	Pecan	April, May
<i>Pistacia</i> species	Pistachio	April
<i>Platanus</i> species	Sycamore	April, May
<i>Prosopis juliflora</i>	Mesquite	April, May
<i>Salix gooddingii</i>	Willow	March, April

*All months shown are inclusive of time of pollination.

Atmospheric Survey.—Tables II, III and IV list monthly and yearly totals of all pollen grains and fungus spores counted. At the end of Tables II and III the pollen index for *Franseria* species was calculated as specified by the American Academy of Allergy and outlined by Durham.¹⁷

Because of the difficulty in differentiating the species of pollen grains in certain genera, it became necessary to report these species together under their respective genus. *Allenrolfea occidentalis*, *Bassia hyssopifolia*, and *Suaeda torreyana* are included in the category “*Chenopodium* species and miscellaneous chenopods,” as the pollen grains all appear morphologically similar to those of *Chenopodium* species. The same is true for the nearly identical pollen grains of *Cupressus* species and *Juniperus* species, which have been combined. No attempt was made to differentiate the species of fungus spores. The spores of the fleshy fungi were labeled mushroom spores, and the rust spores were listed under the order Uredinales.

*Climatologic Data.**—The climate of the metropolitan Phoenix area is considered subtropical, with an average mean temperature ranging from 53° F. in the winter to 87° F. in the summer and a 28° F. average diurnal temperature variation. Although considerable irrigation water flows through the valley, the dry air is not easily saturated and the average mean relative humidity is a low 43 per cent saturation. Precipitation occurs chiefly during two parts of the year. There is a primary maximum fall during the summer months, from June through September, consisting of rains that are local in character; a second maximum fall comes during the winter season, December through March, resulting from a general storm movement from the northwest. Little precipitation occurs during the vernal and autumnal seasons. The average total annual rainfall is approximately 7.5 inches. Winds are predominantly

*Climatologic data obtained from United States Department of Commerce Weather Bureau local summary, Phoenix, Arizona.

TABLE III. MONTHLY AND YEARLY TOTALS
PHOENIX, ARIZONA

SCIENTIFIC NAME	1957						1958						TOTAL	PER CENT	
	JUNE	JULY	AUGUST	SEP- TEMBER	OCT- TOBER	NOVEM- BER	DECEM- BER	JANU- ARY	FEBRU- ARY	MARCH	APRIL	MAY			
Pollen Grains per Cubic Yard of Air															
<i>Amaranthus palmeri</i>	8.4	7.0	66.4	115.1	61.7	3.7	0.6							262.9	5.3
<i>Atriplex</i> species	17.8	8.9	113.0	92.5	37.3	2.5	0.8			1.6		2.1		276.5	5.5
<i>Beta vulgaris</i>	5.8									2.5	4.2	50.7		63.2	1.3
<i>Chenopodium</i> species and miscellaneous cheno- pods		1.7	1.2	17.5	10.8		0.3	0.3	2.4	5.6	1.7			41.5	0.8
<i>Salsola kali</i>		0.6	1.2	3.6	13.7		1.2				1.2	5.4		26.9	0.5
<i>Sarcobatus vermiculatus</i>				13.9										13.9	0.3
<i>Dicoria canescens</i>	3.3	1.2		22.1	52.0	8.5	1.3	10.3	26.2	154.5	590.0	105.0	974.4	19.6	1.6
<i>Franseria</i> species					19.8					4.5	53.9	1.5	79.7	1.6	8.0
<i>Hymenoclea</i> species	56.6	22.6	19.7	46.0	24.5	1.5	1.9			31.3	95.7	102.7	402.5	1.1	1.1
<i>Cynodon dactylon</i>	10.8	3.6	6.2	14.2	3.0	0.4		6.2	22.8	3.2	4.8	8.9	55.1	1.1	1.6
<i>Sorghum halepense</i>										48.1	3.5		80.6	1.6	0.6
<i>Plantago</i> species									0.9	16.8	4.9	5.7	28.3	0.6	15.3
<i>Rumex</i> species										67.0	129.6	31.5	761.5	15.3	18.0
<i>Cupressus-Juniperus</i>				2.8	3.0	18.8	247.6	128.8	132.4	737.2	6.0		895.8	18.0	14.4
<i>Fragaria velutina</i>								1.2	151.4	664.5	38.1		702.6	14.4	3.4
<i>Morus</i> species											29.6	141.5	171.1	3.4	2.6
<i>Olea europaea</i>								36.3	89.3	6.5			132.1	2.6	0.1
<i>Populus fremontii</i>										6.7			6.7		
<i>Ulmus</i> species															
Pollen Grains per Square Centimeter per Slide															
<i>Pinus</i> species								0.3		5.3		20.2	25.9		
<i>Pistachia</i> species										19.6	33.4		53.0		
<i>Prosopis juliflora</i>										6.2	15.1		21.3		
<i>Ricinus communis</i>					1.4			1.0	0.4				3.2		
Miscellaneous grass		0.4							3.6	6.5	4.9		29.2		
Miscellaneous	2.8	6.8	10.8	9.1	20.3	2.0	6.4	21.3	7.8	27.7	31.9	21.3	168.2		

Pollen Index = $\frac{974}{200}$ (season total) + 11 $\left(\frac{\text{number of days with count over 25}}{65} \right)$ + $\frac{65}{100}$ (highest count) = 16.5.

TABLE IV. MONTHLY AND YEARLY TOTALS

SCIENTIFIC NAME	FUNGUS SPORES PER SQUARE CENTIMETER PER SLIDE												PER CENT		
	1957						1958								
	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY		TOTAL	

out of the east, with an average velocity of 5 m.p.h.; however, gales up to 40 m.p.h. have been recorded. Air turbulence and heat convection currents are responsible for vertical movement and a thorough mixing of atmospheric allergens. For these reasons, most of the pollen grains and fungous spores are caught in the morning and late afternoon hours. The average per cent of possible sunshine is 84 for the Phoenix area, although during the twelve months of this study it was 89 per cent, a very important factor in the production of pollen. In 1957 the average daily mean temperatures were 90° F. for the summer and 56° F. for the winter. This indicates a slightly warmer twelve months than normal. The average daily mean relative humidity was calculated to be 47 per cent, with an average daily maximum of 64 per cent daily at 5 A.M. and an average daily minimum of 30 per cent recorded at 5 P.M. each day. The total rainfall was found to be 8.2 inches, which is not much more than average; however, the month of September was unusually dry, with no precipitation, and the month of October had an unexpected 2.2 inches of rain. Because of this adversity, the temperature, precipitation, and relative humidity recorded during these two months were plotted on a graph (Fig. 1) along with the pollen grain count from the two stations in order to establish any possible relationship between climatologic factors and the concentration of atmospheric allergens. A conspicuous negative correlation is found between daily average maximum per cent relative humidity and the daily total pollen count per 2.42 square centimeters on a slide. There seems to be a general increase in number of pollen grains with a decrease in relative humidity, and vice versa. In order to substantiate this relationship, a scatter diagram (Fig. 1) was constructed, relating the relative humidity with total pollen counts. In addition to this, regression values were calculated and the coefficient of correlation was determined to be 0.967, which denoted a very close association. This relationship between relative humidity and pollen counts has been demonstrated experimentally by Shapiro and Rooks¹⁸; therefore, the present findings are merely supportive.

DISCUSSION

The metropolitan Phoenix area lies about 1,100 feet above sea level in the middle of the largest and most fertile valley in Arizona, the Salt River Valley. Desert mountains surround this valley on all sides, with the exception of the southeast, giving the impression of a large oval amphitheater, roughly forty miles long and twenty miles wide. The Salt River contributes most of the very important and much needed water for the valley, entering from the east out of the Arizona Highlands. Water storage and irrigation are regulated by a number of dams constructed on the river. This regulation, beginning with the completion of Roosevelt Dam in 1911, has resulted in a very large and efficient irrigation system controlled chiefly by the Salt River Valley Water Users Association. The Salt River Project irrigates 240,000 acres of highly developed agricultural land. In addition to this, 95,000 acres are under irrigation controlled by other projects in the valley.

Two general categories of plants contribute atmospheric allergens in the Phoenix area. One group includes the mesophytic species which are dependent to a great extent on the presence of water and, for that reason, are limited to

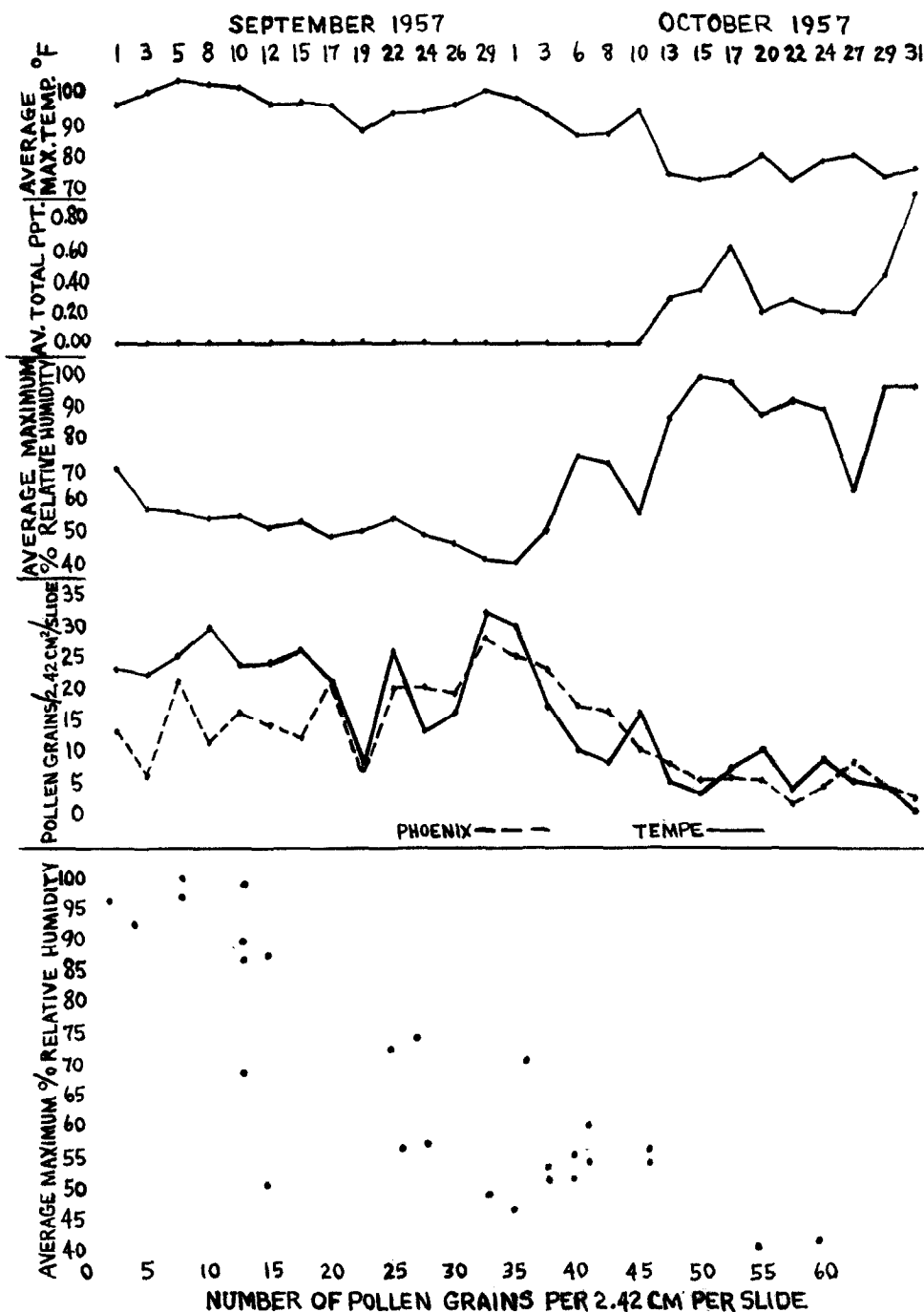


Fig. 1.—Comparison of counts with climatologic data.

irrigated and cultivated areas. The second group includes the native xerophytic vegetation of the desert areas. Within each of these groups there are plants which can be classified as short-term pollinators, assuming importance briefly during the year, and there are others which shed pollen over a much longer period of time.

As mesophytic plants, most of the trees in the metropolitan Phoenix region are restricted to sites along water courses, and canals and in adequately watered residential areas. In general, the trees are short-term anemophilous pollinators, exhibiting definite seasonal periodicity in the production of pollen. Furthermore, a definite sequence is evident in the appearance of pollen from various tree species, although there is an overlapping from one to the other.

The first tree to reach anthesis is *Populus fremontii* Wats., the cottonwood, which is a very common tree native to the Salt River Valley. The pollination period is of short duration, usually extending from the middle of January to early March.

Fraxinus velutina Torr., the Arizona ash, is the next to shed its pollen, beginning about the first of February and continuing until the first of April. It is of secondary importance as a contributor to atmospheric pollen concentrations. (It may be noted in Table III that the Arizona ash pollen was extremely high in the Phoenix count, probably because of two very large ash trees near the sampling device.)

Toward the middle of March, the mulberry trees (*Morus* species) begin to pollinate, surrendering great quantities of pollen throughout April. The "male" mulberry has become the most popular shade tree in the valley, and counts of over 400 grains per cubic yard of air have been recorded at the Tempe station. However, these large counts were probably due to the many mulberry trees planted on and around the campus of Arizona State University. The Phoenix counts were much lower, and the botanical survey of that area revealed fewer mulberry trees. At any rate, *Morus* species can be considered first in concentration of atmospheric pollen grains under the class of short-term pollinators in the valley.

Olea europaea L., the olive tree, is the last of the short-term pollinating trees, blooming from early April until the end of May. This species is common in the valley, where it has been introduced for commercial and landscaping purposes. The "heavy" pollen of *Olea europaea* is transported largely by insects, but it is produced in such quantities that much of the pollen becomes wind-borne and, therefore, is considered an important allergen. The atmospheric concentrations of pollen from the olive trees are approximately equal to those of Arizona ash, although they appear at different times.

Certain conifers are important sources of pollen during the fall and winter months, and because their pollen grains are morphologically similar they are reported together in this study as a single group of long-period pollinators. Toward the end of September, *Juniperus horizontalis* Moench. and various other horticultural varieties of juniper begin to release pollen. Their period of pollination is overlapped by that of the native cypress, *Cupressus arizonica* Greene and the exotic Italian cypress, *Cupressus sempervirens* L. These cypress

trees begin to shed pollen in small amounts in December, increasing their production sporadically throughout the winter and spring months. Both species are popular landscaping trees in the metropolitan area.

One of the most important sustaining pollinators of the irrigated land is Bermuda grass, *Cynodon dactylon* (L.) Pers. This grass is used for most of the lawns in the Phoenix region and is present on most pasture land and moist areas of the Salt River Valley. An extremely hardy grass, it usually begins pollination around the last of February and reaches its peak in April and May. Its pollen remains constant at a lower level through the summer and early fall and finally decreases to negligible amounts in November. In the frost-protected areas along the periphery of the Salt River Valley, however, Bermuda sheds pollen all year.

The only other specific grass considered in this study was *Sorghum halepense* (L.) Pers., known as Johnson grass. Although it is large and conspicuous along roadsides, irrigation canals and cultivated fields, it does not shed much pollen. As Phillips⁸ describes Johnson grass, "Its pollen output does not correspond to its bulk." Contributions from the remainder of the grasses found in the valley were listed as miscellaneous grass pollen, since they were difficult to differentiate and were present in very small amounts.

Amaranthus palmeri Wats., commonly known as careless weed or Palmer's amaranth, rates special consideration among the mesophytic hay fever plants dependent upon cultivation. This herbaceous annual is abundant on irrigated land and along roadsides, washes, and canals and is particularly concentrated in citrus groves, where it is grown as a cover crop. Its pollen begins to appear around the first of May and becomes quite abundant in late summer and early fall. During the month of September, at the Tempe station, a total count of 283.5 pollen grains per cubic yard of air was recorded, establishing this plant as the most important early-fall pollinator.

The xerophytic flora of the deserts and arid mountains, which comprise a large portion of the Salt River Valley and surroundings, includes several important anemophilous plants. The dominant hay fever plants are the several species of the genus *Franseria*. These are the desert false ragweeds or the bur sages.

The principal contributor of atmospheric allergens in this genus is *Franseria deltoidea* Torr., the rabbit bush, one of the climax plants in the desert plant succession. This perennial shrub is the worst offender in causing hay fever from the last of February through May. A less abundant perennial, *Franseria dumosa* Gray, the desert ragweed, pollinates in the spring and has been observed to pollinate again in the fall in some areas of the valley. Another spring pollinator belonging to this genus is *Franseria ambrosioides* Cav., the canyon ragweed, usually found in moist depressions on the desert or along roadsides and canals. A fourth species, *Franseria confertiflora* (DC.) Rydb., the slender ragweed, is not a desert inhabitant but should be mentioned here. This herbaceous plant grows rank in the late summer and fall along canals and irrigated fields and is responsible for pollen sensitivity from late August through

November. The pollens of the four *Franseria* species are morphologically indistinguishable, and no attempt was made to differentiate them.

The members of *Franseria*, as a group, were found to be the greatest contributors of atmospheric pollen, excluding the trees, during February, March, and April at both sampling stations. They also claimed first position at the Phoenix station during the month of May. (Bermuda grass was more concentrated during May at the Tempe station.) The pollen index for *Franseria* species was calculated for each station. (Tables II and III.) The index for the Tempe area during the period from June 1, 1957, through May 31, 1958, was 28.7, and the index for the Phoenix area during the same period was 16.5. These indices are to be compared with the previously reported index of 0.21 for the Phoenix area, as reported in the JOURNAL OF ALLERGY.¹⁸ The last figure was derived from studies made during the fall only, when the pollen concentrations of *Franseria* are at their lowest.

The true ragweeds of the genus *Ambrosia*, which pollinate in the fall, are not found in the valley and, for this reason, the metropolitan Phoenix area has acquired the reputation of being a hay fever-free resort. Phillips,⁶ however, found that persons susceptible to the allergenic reactions of *Ambrosia* have nearly a 50 per cent chance of being affected by *Franseria* their first season in the valley, and many more will become sensitized following exposure.

Some other important anemophilous plants of the desert also belong to the composite family, as do the false ragweeds. These are two species of *Hymenoclea*, burrobrush, and *Dicoria canescens* Gray, a fall pollinator of less importance. *Hymenoclea salsola* Torr. and Gray, a spring pollinator, contributes more pollen to the atmosphere than *Hymenoclea monogyra* Torr. and Gray. The latter is very conspicuous along roadsides and river beds during the fall when it pollinates.

The genus *Atriplex*, the saltbushes, includes another very important group of xerophytic hay fever plants. The first to appear is *Atriplex elegans* (Moq.) Dietr., scattered sporadically all over the valley and pollinating during April and May. *Atriplex wrightii* Wats., the annual saltbush, appears later, shedding a considerable amount of pollen through the summer and early fall months. Three perennial shrubs—*Atriplex lentiformis* (Torr.) Wats., *Atriplex canescens* (Pursh) Nutt., and *Atriplex polycarpa* (Torr.) Wats.—also pollinate during this period. All five species were counted and recorded together as one group, *Atriplex* species. The pollen counts for members of this genus were higher at the Phoenix station than at the Tempe station. These are halophytic plants and are indigenous in this region to the alkaline soils of the Salt River Valley.

Several other representatives of the Chenopodiaceae family, in addition to *Atriplex*, are important pollen-producing plants in the Phoenix area. Many of these are living on the wide river bottom of the Salt River, which has been left with no surface flow because of the impoundments upstream. *Sarcobatus vermiculatus* (Hook.) Torr., *Allenrolfea occidentalis* (Wats.) Kuntze, *Suaeda torreyana* Wats., several species of *Chenopodium*, and *Salsola kali* L. are conspicuous members of this plant community.

Salsola kali L., the Russian thistle or tumbleweed, has become established on great areas of wastelands, fallow fields, and vacant lots in the valley. In spite of this, the total pollen released by Russian thistles in this region is negligible when compared to that produced in other parts of Arizona and the other western states. Another plant which closely resembles Russian thistle is *Bassia hyssopifolia* (Pall.) Kuntze, smother weed. It and a few mesophytic species of *Chenopodium* are commonly distributed along irrigation canals and roadsides in the valley.

Several plants were of minor importance as sources of air-borne pollen. These belonged to several different ecologic and taxonomic groups. Species of *Plantago*, plantain or Indian wheat, blanket large areas of the desert and contribute to the atmospheric allergens in the early spring. Also the docks, *Rumex crispus* L. and *Rumex hymenosepalus* Torr., shed pollen in small quantities during the spring. The former, called curly dock, is found only in moist places, but the latter occurs in somewhat drier areas in sandy soil. Attempts have been made to grow *R. hymenosepalus*, known as canaigre, for its tannin content.

A successful commercial crop plant grown in the valley is the sugar beet, *Beta vulgaris* L. It is grown for production of seed, and a few thousand acres are harvested yearly. The plants reach anthesis in April and are pollinating at their maximum in May. The seeds are then harvested in June. The pollen counts for this species were greater at the Phoenix station than at Tempe.

Three other minor allergens recorded in this study were pollen grains from *Ricinus communis* L. (castor bean), *Prosopis juliflora* (Swartz) DC. (mesquite), and *Pistacia* species (pistachio). These were unimportant because of the small amount of pollen shed and, in the case of pistachio trees, the sparse distribution.

The pollen grains of *Pinus* species were recorded on several occasions. According to Wodehouse,¹⁹ pine pollen is not an important allergen, but Rowe²⁰ has demonstrated it to be a source of allergies even though reported cases have been rare.

Finally, those pollen grains that could not be identified were labeled "miscellaneous." At least a part of these were pollen grains from entomophilous plants and atypical forms from anemophilous species. It may be noted that an unusually large number of unidentified pollen grains were recorded during the winter months. Many of these were morphologically similar and might have been produced by plants of one genus or species. It is my conviction that, because of their atmospheric incidence, these should be investigated further as possible allergens.

Fungous spores from several species were observed, but only those which positively could be identified by microscopic examination were recorded. Such spores as those from species of *Penicillium*, *Aspergillus*, and *Rhizopus* could not be discerned on the exposed slides. It is believed, however, that they are always present and ubiquitous, for the colonies are generally formed upon exposure of proper media to the air.

Spores of *Alternaria* species were undoubtedly the most concentrated, constituting over 50 per cent of all the spores counted at both stations. It is of particular interest that the heaviest concentration of *Alternaria* spores, as well

as most of the other spores recorded, were found during the late fall and winter months, which is not always the case in other parts of the country. Another interesting result is the year-long concentration of smut spores contributed mainly by smut of Johnson grass, *Sphacelotheca holci* Jackson, and to a lesser extent by smut of Bermuda grass, *Ustilago cynodontis* (Pass.) Curzi.

The report of the occurrence of the fungous spores is merely a preliminary study; more complete and detailed investigations involving culturing methods are necessary. However, a general picture of the seasonal distribution and concentration of fungous spores has been developed on the basis of examination of exposed slides.

Although the concentrations were predominantly higher at the Tempe station, there was a good agreement in the seasonal occurrence of the pollen grains and fungous spores at both stations. One should not conclude, however, that Tempe will necessarily always have a greater concentration of atmospheric allergens than downtown Phoenix.

Another important point is that at no time were there any pollen grains recorded from species of *Quercus* (oak) or *Artemisia* (sage), although these plants are found in abundance at higher elevations to the north and east of the valley. Therefore, there is no evidence that allergens from outside the valley are contributing to the hay fever problem in the Phoenix area.

In comparing the local counts with those of other areas in the United States, it is evident that the summer and fall counts are below average, although spring counts are about as high as those of other sections of the United States. The winter fungous spore concentration is of considerable consequence in the valley. Further investigation should be conducted, comparing these counts with subsequent studies in the Salt River Valley to determine more exact patterns of concentration and seasonal distribution of allergens. Also, more detailed differentiation of the pollen grains should be made, with special emphasis on the winter pollen, so that information will be available as to the presence of more specific allergens.

SUMMARY

1. A botanical survey of the hay fever plants in the metropolitan area of Phoenix, Arizona, is presented.

2. Data are given concerning the kind, concentration, and seasonal occurrence of the atmospheric pollen grains and fungous spores found during a one-year investigation conducted from June 1, 1957, through May 31, 1958, in Phoenix and Tempe, Arizona.

3. *Morus* species (mulberry) and *Fraxinus velutina* (Arizona ash) are found to be the most important tree pollinators contaminating the air in the spring. *Franseria* species (false ragweeds) and *Cynodon dactylon* (Bermuda grass) are heavy pollinators that reach anthesis in the spring and shed pollen sporadically through the summer and fall. (Contrary to popular belief, only one grass—Bermuda—was found to shed great enough concentrations of pollen to be considered significantly important as a general allergen.) *Amaranthus*

palmeri (careless weed) and *Atriplex* species (saltbush) are heavy contributors to the atmospheric pollen in the summer and fall months, the careless weed being the most important. Finally, the fungous spores are found in the air year round, with spores of *Alternaria* species the most prevalent.

4. It is concluded that a definite allergy problem exists in the Phoenix area and the Salt River Valley, as evidenced by the presence of allergens in the air throughout the year.

The cooperation and assistance of many persons too numerous to mention were necessary in conducting this investigation. I am particularly indebted to Dr. James A. McCleary for his inspirational guidance and advice during the course of this research and to the other members of my committee—Drs. Ronald R. Clothier, Edward E. Burgoyne, and Herbert L. Stahnke—for their criticisms and suggestions. I am also grateful to Dr. Charles W. Vivian and members of the Greater Arizona Chapter of the Allergy Foundation of America for their interest and consideration in this study. Finally, I wish to express my gratitude to Dr. Chester R. Leathers for his valuable assistance in the identification of the fungous spores and the editing of the manuscript.

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