DOCTORAL DISSERTATION SERIES

PUBLICATION: 7718

AUTHOR: John Arvid Schmitt, Jr., Ph. D., 1954
University of Michigan

TITLE: THE HOST SPECIALIZATION AND MORPHOLOGY OF THE POWDERY MILDEW, ERYSIPHE CICHORACEARUM DC. EX MÉRAT, FROM ZINNIA, PHLOX AND CUCURBITS

University Microfilms, Ann Arbor, Michigan

THE HOST SPECIALIZATION AND MORPHOLOGY OF THE POWDERY MILDEW, ERYSIPHE CICHORACEARUM DC. EX MÉRAT, FROM ZINNIA, PHLOX AND CUCURBITS

by

John Arvid Schmitt, Jr.

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the
University of Michigan
1953

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THE HOST SPECIALIZATION AND MORPHOLOGY OF THE POWDERY MILDEW, ERYSIPHE CICHORACEARUM DC. EX MÉRAT, FROM ZINNIA, PHLOX AND CUCURBITS

by John Arvid Schmitt, Jr.

This investigation is a study of the powdery mildew, Erysiphe cichoracearum DC. ex Mérat sensu Salmon. It was obtained from zinnia (Zinnia elegans), cultivated perennial phlox (Phlox paniculata, P. maculata or their hybrids), squash (Cucurbita pepo), Cerinthe major, Inula helenium and Helianthus annuus. The host specialization of the mildew from these sources was studied and is compared with the host specialization of special forms in the species or of biologic species separated from it. A comparative morphological study of the special forms investigated was carried out. A discussion of these aspects is given in connection with the species concepts of Blumer and Salmon.

The infection experiments were performed using seedlings, usually at the two- or four- leaf stage. For the greater part of this phase of the study inoculations were made using a dusting technique, although earlier a conidial suspension method was used.

The morphological study was carried out using both fresh and herbarium materials. Perithecia were measured for diameter and checked for the number of ascospores per ascus and perithecial appendage length and coloration. The conidia were measured for length and width; other characters such as color and shape, were noted. For all measurements the range, mean and standard deviation are given.

A powdery mildew from Zinnia elegans is shown to infect Z. elegans, Z. pauciflora, Z. verticillata, Helianthus annuus, Arctium minus, A. nemorosum, Xanthium chinense, X. spinosum, X. strumarium, Mikania

scandens, Hieracium alpinum, H. prenanthoides, Inula helenium, Carlina acaulis, Lactuca perennis, Cosmos sp., Scorzonera hispanica and Felicia amelloides of the Compositae, Salpiglossis sinuata of the Solanaceae and Cerinthe major of the Boraginaceae. A phlox mildew is shown to be restricted to Phlox drummondii and the cultivated perennial phlox, no infection occurring on thirty-four other species of hosts which have been reported for Erysiphe cichoracearum. A cucurbit mildew from the vicinity of Ann Arbor is shown to be restricted to the Cucurbitaceae. Reed's infection of Helianthus annuus and Plantago rugelii by a cucurbit mildew was not duplicated.

A comparison of the perithecia of the phlox and zinnia mildews and of the conidia of the phlox, zinnia and cucurbit mildews failed to provide differences to justify specific separation.

The zinnia, phlox and cucurbit mildews are best recognized as special forms of Erysiphe cichoracearum sensu Salmon, distinguished by marked differences in their host specialization, but not by morphological differences.

PREFACE

The writer wishes to express his sincere gratitude to the members of his committee for the assistance they have given him. Special thanks are due Dr. E.B. Mains, Chairman, whose willing guidance and counsel have helped immensely in the completion of this study.

To the personnel of the University of Michigan Botanical Gardens and in particular to Mr. Walter Kleinschmidt, Superintendent, the writer wishes to express his appreciation for the assistance they have so freely given and for making space available for performing the infection experiments herein reported.

Appreciation is also extended to Dr. Bessie B. Kanouse, Curator of the Mycological Herbarium, University of Michigan, for loaning the writer the specimens of Erysiphe cichoracearum from which the morphological study was made.

I wish to thank Mr. Edward Pescynski who graciously translated papers in Polish and Russian for me.

The writer wishes to express his sincere gratitude to the individuals and institutions that supplied the seeds of the species of hosts used in this investigation . A list of the species follows the name of the individual or institution. The names are cited as indicated on the seed packet. The New York Botanic Gardens, New York, N.Y. - Centaurea jacea, C. scabiosa, Inula helenium and Rudbeckia hirta; The Morris Arboretum, University of Pennsylvania, Philadelphia, Pa. Mikania scandens; Canadian Department of Agriculture, Ottawa, Ontario, Canada - Carduus acanthoides, C. nutans and Cichorium intybus; Dominion Arboretum and Botanic Gardens, Ottawa, Ontario, Canada -

Cirsium arvense, C. vulgare, Plantago major, P. media, P. rugelii, Petasites sagittatus, Xanthium (canadense) chinense, Echinocystis lobata and Sicyos angulatus; Botanical Gardens of the University, Erlangen, Germany - Adenostyles glabra, Centaurea macrophylla, Carlina acaulis, Calendula officinalis, Hieracium murorum, Plantago maritima, P. alpina, P. coronopus, Stachys palustris, Xanthium strumarium, X. spinosum, Cerinthe minor, Artemisia absinthium, A. vulgaris, Lactuca perennis, Bryonia dioica, Citrullus calocynthidis, Eupatorium cannabinum and Verbascum nigrum; Botanical Garden of the University, Lisbon, Portugal - Lapsana communis, Cerinthe major and Cobaea scandens; Royal Botanic Gardens, Edinburgh, Scotland - Prenanthes purpurea; Herbarium and Botanic Gardens of the University of British Columbia, Vancouver, B.C., Canada - Erigeron glabellus and Aster alpinus; Botanic Garden of the University, Budapest, Hungary - Artemisia campestris, Momordica charantia, Cardamine impatiens, Cirsium canum, C. rivulare, and Lactuca serriola; Botanic Gardens, Slovakian University, Bratislava, Czeckoslovakia - Cucurbita melanosperma, Cyclanthera pedata and Benincasa hispida; Palmengarten, Frankfurt, Germany - Hieracium pilosella, Polemonium flavum and P. pauciflorum; Botanic Gardens of the University, Uppsala, Sweden - Centaurea melitensis, Hieracium alpinum, H. amplexicaule, H. prenanthoides, H. silvaticum, Zinnia pauciflora, Z. verticillata, Gilia millefoliata, G. androsacea, G. multicaulis, Polemonium filicinum and Galium aparine; Botanic Garden, University of Karlova, Prague, Czeckoslovakia - Callomia abrotanifolia, C. linearis, C. squarrosa, Gilia aggregata, G. achilleifolia, G. laciniata, Navarretia squarrosa, Polemonium carneum, P. reptans, P. viscosum, Actinomeris squarrosa, Ambrosia psilostachya, Arctium

nemorosum, Crepis foetida, C. sibirica, Felicia amelloides, Scorzonera hispanica and Sonchus palustor; Botanic Gardens of the University of Michigan - Nicotiana tabacum, Helianthus annuus, Antirrhinum majus, Tanacetum vulgare and Helichrysum bracteatum; Dr. C.D. La Rue - Salpiglossus sinuata; Mr. Anson Cooke - Hyoscyamus niger; Dr. E.B. Mains - Cucurbita pepo, strains CP 434 Al, 25-5XX and Zuccini X White Disk; Mr. Rex Pearce - Centaurea dealbata, Dahlia sp.(annual), Anchusa italica, Polemonium van-bruntiae, Teucrium chamaedrys and Salvia glutinosa.

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INTRODUCTION

I. Statement of the Problem:

This investigation is a study of Erysiphe cichoracearum DC. ex Mérat sensu Salmon. It was obtained from zinnia (Zinnia elegans), cultivated perennial phlox (Phlox paniculata, P. maculata or their hybrids), squash (Cucurbita pepo), Cerinthe major, Inula helenium and Helianthus annuus. The host specialization of the mildews from these sources was studied and is compared with the host specialization of special forms in the species or of biologic species separated from it. A comparative morphological study of the special forms investigated was carried out. A discussion of the results of the host specialization and the comparative morphological study is given in connection with the species concepts of Salmon and Blumer.

II. Review of the Literature:

Erysiphe cichoracearum DC. ex Mérat is a species of the powdery mildews. These are a group of obligate parasites belonging to the Class Ascomycetae, Order Erysiphales and Family Erysiphaceae. The genus Erysiphe has one-celled ascospores, perithecia without an ostiole and normally containing several to many asci, perithecial appendages simple and hypha-like, mycelium external and conidia non-septate, colorless or white and produced in chains. Salmon (1900) characterized Erysiphe cichoracearum thus:

> Mycelium amphigenous, evanescent or persistent and effused, usually white; perithecia subglobose, gregarious or scattered, 80-140, rarely 140-180 microns in diameter; appendages variable, long or short, brown or colorless, numerous, densely interwoven, from 2-4 times the diameter of the perithecium; asci numerous, usually 10-15, variable

in size and shape, more or less stalked, 58-90 X 30-50 microns; spores 2, rarely and never uniformly 3, 20-28 X 12-20, usually 24 X 14 microns.

Salmon's Monograph of the Erysiphaceae (ibid.) is a treatment of the powdery mildews of the world. It is the only such extensive monograph of this group and as such it has been used generally. Salmon placed greatest emphasis in species delimitations on morphological characteristics, i.e., on characters of the haustoria, the perithecia and their appendages, and the asci and ascospores. In most species his concept results in a wide range of species of host plants. This is especially true in his treatment of Erysiphe cichoracearum. He lists for this mildew two hundred seventy-six species of hosts in one hundred fifteen genera of twenty-six families of flowering plants. These are enumerated in Table I.

The valid name for this powdery mildew is somewhat in dispute. Cooke (1952) has pointed out that the name Erysiphe cichoracearum DC. (De Candolle, 1805) is pre-Friesian and has no standing. He suggested that the valid name for E. cichoracearum sensu Salmon should be E. communis Wallr. ex Fr. This Friesian name included mildews on several families of higher plants. According to Salmon, it included mildews from the following species; Sphaerotheca humuli (DC.) Burr., and var. fuliginea (Schlecht.) Salmon; Microsphaera astragali (DC.) Trev.; Erysiphe polygoni DC.; E. cichoracearium DC.; E. galeopsidis DC.; and E. graminis DC. According to the species of hosts listed E. communis of Fries was primarily E. polygoni of Salmon. For this reason we do not agree with Cooke that the valid name for E. cichoracearum DC. sensu Salmon is E. communis Wallr. ex Fr. This leaves the species as treated by Salmon without a Friesian name. In Mérat's Nouvelle flore des environs de Paris, 2 Ed. Vol. 1 (1821) the name E. cichoracearum DC. is used.

Rogers (1951) has established that Merat's is the first post-Friesian publication since according to the latest International Rules of Botanical Nomenclature the date for all volumes of Fries' Systema Mycologicum is Jan.1,1821. Merat's use of E. cichoracearum DC thus validates the name for this species.

Other mycologists who have recognized E. cichoracearum as occurring on many families of flowering plants are Winter (1884), Burrill in Ellis and Everhart's North American Pyrenomycetes (1892), Magnus (1898), Reed (1913) and Jørstad (1925).

Erysiphe cichoracearum was described by A.P. de Candolle (1805) as occurring on the Cichoriaceae, specifically on Scorzonera hispanica and Tragopogon porrifolius. His description emphasizes morphology, although no actual measurements are given, to distinguish this species from several others. Wallroth (1819) treats the powdery mildews on a morphological basis. He recognized Alphitomorpha communis, relegating E. cichoracearum DC. to synonomy. Under A. communis he designated several varieties according to the family of host plants. Fries (1829) transferred A. communis Wallr. to Erysiphe. He similarly recognized it as a large species under which he designated six varieties, each occurring on various species from twenty-three families. Duby (1830) recognized eight varieties of E. communis according to the family of hosts; one variety was cichoracearum under which was listed E. cichoracearum DC. as a synonym.

Schlechtendal (1824) recognized Erysibe communis on the Leguminosae, Polygonaceae, Convolvulaceae, Onagraceae and Boraginaceae.

Léveillé (1851), Cooke and Peck (1872) and Jaczewski (1896) treated Erysiphe cichoracearum DC. under E. lamprocarpa (Wallr.)

Table I: Host plants, according to families and genera, of *Erysiphe cichoracearum* sensu Salmon (The number in parenthesis indicates the number of species cited).

Compositae:

- Achillea (2)
- Actinomeris (1)
- Adenostyles (2)
- Ambrosia (3)
- Aplopappus (1)
- Arctium (3)
- Artemisia (9)
- Aster (28)
- Balsamorhiza (1)
- Bigelovia (1)
- Boltonia (1)
- Calendula (1)
- Carduus (3)
- Carlina (1)
- Centaurea (4)
- Chrysopsis (1)
- Cichorium (1)
- Cnicus (9)
- Crepis (2)
- Crupina (1)
- Dahlia (1)
- Dyssodia (2)
- Erigeron (7)
- Eupatorium (3)
- Gaillardia (1)
- Gnaphalium (1)
- Grindelia (1)
- Gutierrezia (1)
- Helenium (1)
- Helianthella (1)
- Helianthus (11)
- Helichrysum (1)
- Helichrysum (1)
- Hieracium (9)
- Hyoscyamus (2)
- Inula (5)
- Iva (2)
- Kuhnia (1)
- Lactuca (4)
- Lapsana (1)
- Lygodesmia (1)
- Madia (1)
- Mikania (1)
- Onopordum (1)
- Prenanthes (2)
- Rudbeckia (2)
- Saussurea (1)
- Scorzonera (3)
- Senecio (3)
- Sesbania (1)
- Silphium (1)
- Solidago (6)
- Sonchus (3)
- Stevia (1)
- Tanacetum (1)
- Taraxacum (1)
- Tragopogon (2)
- Verbesina (2)
- Vernonia (3)
- Xanthium (2)

Boraginaceae:

- Amsinckia (1)
- Anchusa (2)
- Asperugo (1)
- Borago (1)
- Cerinthe (1)
- Cynoglossum (2)
- Echium (3)
- Lappula (3)
- Lithospermum (2)
- Lycopsis (1)
- Mertensia (2)
- Myosotis (3)
- Onosma (1)
- Pulmonaria (2)
- Symphytum (2)

Labiatae:

- Ballota (1)
- Lycopus (1)
- Mentha (2)
- Phlomis (1)
- Prunella (1)
- Slavia (1)
- Scutellaria (1)
- Stachys (1)
- Teucrium (2)

Scrophulariaceae:

- Antirrhinum (1)
- Mimulus (1)
- Verbascum (5)

Hydrophyllaceae:

- Ellisia (1)
- Hydrophyllum (5)
- Phacelia (2)

Leguminosae:

- Trigonella (1)

Urticaceae:

- Laportea (1)
- Parietaria (3)
- Pilea (1)

Verbenaceae:

- Verbena (8)

Polemoniaceae:

- Phlox (3)

Rosaceae:

- Geum (1)
- Potentilla (3)

Solanaceae:

- Nicotiana (1)
- Solanum (1)

Polygonaceae:

- Eriogonum (1)
- Rumex (1)

Rubiaceae:

- Asperula (1)
- Galium (3)

Cucurbitaceae:

- Cucurbita (1)

Apocynaceae:

- Apocynum (1)

Asclepiadaceae:

- Asclepias (1)

Campanulaceae:

- Campanula (3)

Plantaginaceae:

- Plantago (9)

Cannabinaceae:

- Humulus (1)

Bignoniaceae:

- Campsis (Tecoma) (1)

Ranunculaceae:

- Clematis (1)

Valerianaceae:

- Valeriana (1)

Onagraceae:

- Epilobium (1)

Hypericaceae:

- Hypericum (1)

Malvaceae:

- Napaea (1)

Cruciferae:

- Cardamine (1)

Duby.

Starting with Marchal (1902, 1903), who worked with Erysiphe graminis, rather intensive series of infection experiments was begun to determine the host specificity of the mildews. These have shown in many instances rather restricted specialization of the mildews to closedly related hosts.

Jaczewski (1927) recognized Erysiphe cichoracearum primarily on morphological bases. Within this species he designated one hundred twelve different forms, separated one from the next by host differences. On several of the larger genera of hosts, as in Centaurea, more than one form of mildew was recognized. These could be distinguished by a different series of host species which they could infect. Some of these special forms had been established as a result of infection experiments carried out by him and by other workers. Since no infection experiments were mentioned for the greatest number of the forms the restriction was apparently assumed because of the occurrence on different hosts.

Blumer (1933) published a monograph of the powdery mildews of middle Europe, especially of Switzerland. He separated his species by much smaller morphological differences than Salmon. Blumer correlated these differences with rather marked differences in the species of hosts. In some instances Blumer's criteria were supported by the results of infection experiments performed by him or by other investigators. As a result of this restricted species concept Blumer limited Erysiphe cichoracearum primarily to the Compositae, on one hundred five species in the thirty-eight genera as shown in Table II.

Through these narrower species concepts Blumer was able to separate ten species of mildew from E. cichoracearum sensu Salmon. In addition

Table II; Compilation of the families and genera of hosts for the species segregated by Blumer (1933) from Erysiphe cichoracearum sensu Salmon. (The number in parenthesis is the number of species cited.)

Erysiphe cichoracearum sensu Blumer:

Compositae:

Achillea (3)	Echinops (1)	Rhaponticum (1)
Adenostyles (1)	Eupatorium (1)	Scorzonera (3)
Aster (11)	Filago (1)	Senecio (4)
Carlina (1)	Gnaphalium (2)	Silybum (1)
Carduus (6)	Helichrysum (2)	Solidago (2)
Centaurea (12)	Hieracium (12)	Sonchus (5)
Cichorium (2)	Hyoscyamus (1)	Tanacetum (1)
Cirsium (5)	Hypochaeris (2)	Telekia (1)
Cnicus (1)	Inula (2)	Tragopogon (3)
Crepis (3)	Lactuca (4)	Tussilago (3)
Crupina (1)	Leontodon (2)	Xanthium (2)
Dahlia (1)	Petasites (1)	Xeranthemum (1)
Dendroseris (1)	Prenanthes (1)	

Polemoniaceae: Polemonium (1)
Solanaceae: Nicotiana (1)
Violaceae: Viola (3)

E. montagnei Lev.: Compositae: Cirsium (9)

E. depressa (Wallr.) Schlecht.: Compositae: Arctium (5) and Onopordum (1)

E. artemisiae (Wallr.) Grev.: Compositae: Artemisia (4)

E. fischeri Blumer: Compositae: Senecio (3)

E. horridula (Wallr.) Lev.: Boraginaceae:

Anchusa (3)	Echium (1)	Myosotis (6)
Asperugo (1)	Lappula (2)	Nonnea (2)
Borago (1)	Lithospermum (2)	Pulmonaria (4)
Cerinthe (2)	Lycopsis (1)	Symphytum (3)
Cynoglossum (2)		

E. labiatarum (Wallr.) Chev.: Labiatae: Lycopus (1), Mentha (3), Prunella (2), Thymus (1)

E. salviae (Jacz.) Blumer: Labiatae: Salvia (6)

E. lamprocarpa (Wallr.) Duby: Plantaginaceae: Plantago (13)

E. verbasci (Jacz.) Blumer: Scrophulariaceae: Verbascum (8)

E. valerianae (Jacz.) Blumer: Valerianaceae: Valeriana (6)

to E. cichoracearum the following were recognized: Erysiphe fischeri, sp. nov., E. valerianae (Jacz.) Blumer, E. salviae (Jacz.) Blumer, E. verbasci (Jacz.) Blumer, E. horridula (Wallr.) Lév., E. montagnei Lév., E. depressa (Wallr.) Schlecht;, E. labiatarum (Wallr.) Chev., E. lamprocarpa (Wallr.) Duby and E. artemisiae (Wallr.) Grev., The host families and genera of these species are included in Table II, and a comparison of the morphological characteristics is given in Table III.

The literature concerning the host specialization of Erysiphe cichoracearum sensu Salmon is distributed in many mycological and pathological papers. The infection experiments performed with this mildew to establish the host specialization will be presented according to the special form of the mildew.

Blumer (1933) has recognized fifteen special forms of Erysiphe cichoracearum. His and other investigators' results, with his distinctions, are summarized as follows with the designations used by Blumer;

f.sp. adenostyles on Adenostyles glabra. Blumer (1922b) postulated that the mildew on this host was restricted since A. glabra was never infected by mildews from other species of hosts used in his experiments.

f.sp. asteris on Aster cordifolius, A. laevis and A. sagittifolius. Reed (1907) reported reciprocal infections by the mildews on these three species of Aster, whereas none of his other mildew assessions infected this genus. Solidago caesia and Cucurbita maxima, Hubbard squash, were not infected.

f.sp. cardui on Carduus sp. In Blumer's experiments (1922b) species of Carduus were not infected by any mildew.

f.sp. centaureae jaceae on Centaurea jacea, C. nigrescens, C. transalpina, C. macrocephala, C. phrygia, C. pseudophrygia, C. mollitensis, C. carniolica and probably other species of Centaurea. (Blumer 1922b)

f.sp. centaureae scabiosae on Centaurea scabiosa. (Blumer, 1922b)

f.sp. centaureae montanae on Centaurea montana (Blumer, 1922b).

f.sp. centaureae dealbatae on Centaurea dealbata. This species of host was not infected by the mildews from Centaurea carniolica, C. scabiosa, C. jacea, C. phrygia or C. montana used by Blumer (1922b) so he concluded there must be a special form on C. dealbata.

Table III: A morphological comparison of the species recognised by Blumer as segregated from Erysiphe cichoracearum sensu Salmon.

Species:	Conidia:	Perithecial diameter:	Perithecial appendages:	Asci:	Ascospores:
Erysiphe horridula (Wallr.) Lév.	ellipsoidal to doliform, 29-40 X 16-22 µ	95-135 (aver.115) µ	varying length, somewhat browned	10-20, 45-80 X 20-45 µ	2, rarely 3 or 4, 18-22 X 15-18 µ
E. montagnei Lév.	ellipsoidal to cylindrical, 32-36 X 15-19 µ	90-108 (aver.99) µ	brown, 2-4 times perithecial diameter, rarely irregularly branched	less than 12	2, rarely 3 or 4, 22-25 X 14-17 µ
E. depressa (Wallr.) Schlecht.	large, doliform 35-42 X 22-26 µ	112-133 (aver.123) µ	equal to perithecial diameter	8-14 (10-12) 60-90 X 30-45 µ	2, 22-32 X 15-20 µ
E. labiatarum (Wallr.) Chev.		rare, 115-135 µ	browned, 1-2 times perithecial diameter	8-15, 50-70 X 25-45 µ	2, 22-25 X 14-16 µ
E. lamprocarpa (Wallr.) Duby	elliptic to rod-shaped, rarely doliform, 35-39 X 16-19 µ	99-121 (aver.110) µ	equal to perithecial diameter, browned, rarely irregularly branched	5-20, 50-65 X 25-45 µ	2, 20-26 X 12-16 µ
E. artemisiae (Wallr.) Grev.	26-32 X 17-22 µ	97-123 (aver.110) µ	hyaline or weakly browned, equal to perithecial diameter	7-20, 55-75 X 25-40 µ	2, 22-28 X 12-17 µ
E. verbasci (Jacz.) Blumer	doliform, 35-40 X 22-24 µ	115-137 (aver.126) µ	poorly formed, scarcely equal to perithecial diameter, rarely irregularly branched	10-20, 60-75 X 30-35 µ	2, 23-27 X 14-19 µ
E. valerianae (Jacz.) Blumer	30-35 X 15-19 µ	101-119 (aver.110) µ	brown, 1-3 times perithecial diameter	10-20, 45 70 X 25-49 u	2, 30-35 X 15-19 µ

Table III: Continued.

Species:	Conidia:	Perithecial diameter:	Perithecial appendages:	Asci:	Ascospores:
Erysiphe salviae (Jacs.) Blumer	ellipsoidal to doliform, 28-35 X 14-18 µ	rare, 88-110 (aver. 100) µ	short, occasionally irregularly branched	6-12, 50-60 X 35-45 µ	2, 17-24 X 12-16 µ
E. fischeri Blumer	28-35 X 14-19 µ	rare, 111-150 (aver. 128) µ	brown, 1-2 times perithecial diameter	15-20, 50-80 X 30-40 µ	2, 20-25 X 14-18 µ
E. cichoraceorum sensu Blumer	25-45 X 16-26 µ	90-135 µ	1-4 times perithecial diameter, rarely irregularly branched	10-25, 60-90 X 25-50 µ	2, rarely 3, 20-28 X 12-18 µ
E. polyphaga Hammarlund	ellipsoidal, cylindrical or doliform, 27.7-32.7 X 14.4-18.2 µ	88-135 (aver. 105) µ	longer than diameter of perithecium, dark brown	8-20	2-4

It is to be noted that in his experiments with the mildew on species of Centaurea no species from other genera were tested.

f.sp. cichorii on Cichorium intybus and C. endivia.

f.sp. cirsii eriophori on Cirsium eriophorum, C. ferox, C. erachnoideum, C. sclerranthum and C. carlinoides. Blumer (1933) states that only with the mildew on C. eriophorum was identification and assignment of the mildew to Erysiphe cichoracearum possible.

f.sp. eupatorii on Eupatorium cannabinum. Blumer (1922b) showed this mildew infected only E. cannabinum, no infection occurring on Solidago virga-aurea, Inula helenium, Lactuca muralis and Adenostyles glabra.

f.sp. euhieracii on Hieracium murorum and twelve other species in the subgenus Euhieracium. In Blumer's experiments (1922b) species of other genera were not inoculated. Neger (1902) inoculated Sonchus oleraceus, Lactuca muralis, Galium silvaticum, Hypericum montanum, Leontodon taraxacum, and Artemisia vulgaris, but no other species of Hieracium.

f.sp. pilosellae on Hieracium pilosella, H. auricula, and H. pratense. Blumer (1922b) infected only H. auricula and H. pratense with the mildew on H. pilosella; species of other genera were not inoculated.

f.sp. prenanthidis on Prenanthes purpurea. Blumer (1922b) found this mildew did not infect species of Cirsium, Hieracium, Centaurea and Sonchus.

f.sp. scorzonerae on Scorzonera hispanica. Bouwens (1927) infected only this host, while negative results were obtained on Phacelia tanacetifolia, Cucurbita pepo, Lappa minor, Borago officinalis, Plantago major, Helianthus tuberosus, Taraxacum officinale, Circaea lutetiana and Caledula officinalis. In all these cases only a few plants were inoculated. In her results with Scorzonera hispanica only four of seven plants were infected.

f.sp. sonchi on Sonchus sp. Blumer (1922b) infected Sonchus oleraceus, S. asper, S. arvensis, S. laciniata, S. paluster and S. tenerissimus with the mildew from an unidentified species of this genus. He later (1926) transferred a mildew occurring on Sonchus jacquini to Sonchus oleraceus, S. asper and S. arvensis. In his earlier work with the mildew of this genus, many species of other genera of composites were not infected.

In the ten species which Blumer segregated from Erysiphe cichoracearum sensu Salmon the following studies concerning host specialization have been made.

In his monograph Blumer recognized Erysiphe montagnei Lév. as occurring on nine species of Cirsium. He stated that the infection experiments he performed (1922b) showed the mildew to be restricted to these nine species of Cirsium. He cites these results to justify the recognition of both E. montagnei and E. cichoracearum f.sp. cirsii eriophori. Biometric studies of conidia from the mildews on these species apparently played a role in his decisions within this genus of host. He gave the following measurements of length to width (1926a) to distinguish E. cichoracearum f. sp. eriophori from E. montagnei: conidia on Cirsium eriophorum - 29.34/16.58 µ equals 1.77; on C. ferox - 29.78/16.68 µ, equals 1.79; on C. oleraceum- 28.27-29.05/14.76-14.81 µ, equals 1.91-1.94; and on C. arvense- 27.9/15.63 µ, equals 1.78.

Erysiphe depressa (Wallr.) Schlecht. is recognized by Blumer (1933) as being restricted to Arctium edulis, A. lappa, A. minus, A. nemorosum and A. tomentosum and questionably on Onopordum acanthium. Neger (1902) established that the mildew on Arctium lappa could not be transferred to Artemisia vulgaris nor Hieracium murorum. Blumer (1922b) transferred the mildew on Arctium minus to A. palladium, A. nemorosum, A. lappa and A. tomentosum; no infection occurred on Onopordum acanthium, Cirsium oleraceum, Carduus crispus, Carlina acaulis, Senecio vulgaris and Plantago major. Bouwens (1927) failed to infect Scorzonera hispanica with a mildew from Arctium minus (Lappa minor).

Blumer (1933) separated Erysiphe artemisiae (Wallr.) Grev. from E. cichoracearum sensu Blumer on the bases of some small morphological differences and the results of Neger's infection experiments with

the mildew on Artemisia vulgaris (1902). In these experiments no infection occurred on Senecio vulgaris, Leontodon taraxacum, Lactuca muralis, Artemisia absinthium, Sonchus oleraceus and Hieracium murorum of the Compositae, Galium silvaticum and G. rotundifolium of the Rubiaceae, Alchemilla vulgaris of the Rosaceae, Ranunculus repens of the Ranunculaceae and Plantago lanceolata of the Plantaginaceae.

Erysiphe fischeri Blumer was segregated from E. cichoracearum sensu Blumer (1933) as occurring on Senecio viscosus, S. silvaticus and S. vulgaris. According to Blumer (1922b) the mildew on Senecio vulgaris infected only the above three species of section Obaejaceae of Senecio. Only species of Senecio were tested. Neger (1902) failed to infect Hieracium murorum, Lactuca muralis, Symphytum tuberosum and Pulmonaria officinalis with a mildew from Senecio vulgaris.

Blumer (1933) recognized Erysiphe labiatarum (Wallr.) Chev. on Thymus, Prunella, Mentha and Lycopus of the Labiatae. The writer has been unable to find any reports of infection experiments using mildews from species of these genera. Blumer has stated that there are probably special forms within E. labiatarum since he found healthy plants of Lycopus europaeus next to strongly infected plants of Mentha aquatica.

Blumer likewise recognized Erysiphe salviae (Jacz.) Blumer on six species of Salvia of the Labiatae. He reported (1933) that he had transferred the mildew on Salvia pratensis to Salvia dumetorum and S. pratensis X S. silvatica, whereas Salvia glutinosa, S. verticillata, S. sclarea, S. officinalis, Lamium amplexicaule and Rosmarinum officinalis were not infected. Laibach (1930) was unable to

transfer the mildew on Salvia verticillata to Salvia pratensis, Lamium galeobdolon or L. purpureum.

Erysiphe lamprocarpa (Wallr.) Duby on thirteen species of Plantago was recognized by Blumer (1933). Salmon (1904) occasionally, but never regularly, was able to transfer the mildew of Plantago major to P. media; P. lanceolata was never infected. Reed (1908) reported Plantago rugelii to be a host for the cucurbit mildew. This indicates that mildews on Plantago may not be restricted to the genus. Blumer (1926a) made successful reciprocal inoculations with the mildews on Plantago major and P. asiatica. Bouwens (1927) inoculated Plantago major, Cucurbita pepo, Scorzonera hispanica and Helianthus annuus with the mildew of Plantago major; only on P. major did infection occur.

Erysiphe verbasci (Jacz.) Blumer was established as occurring on eight species of the genus Verbascum of the Scrophulariaceae by Blumer (1933). Neger (1902) states that the mildew on Verbascum thapsiforme is restricted to this species, and Bouwens (1927) likewise found the mildew on Verbascum thapsus to be restricted. In both of these cases only a few other species were inoculated; no other species of Verbascum nor any other member of the Scrophulariaceae was included.

Erysiphe valerianae (Jacz.) Blumer is another species recognized by Blumer (1933). It occurs on six species of Valeriana. Blumer stated (1933, p.265) that the mildew on Valeriana officinalis had not been investigated with infection experiments, but that this host species had not been infected by any biologic species occurring on the Compositae.

Erysiphe horridula (Wallr.) Lev. was recognized by Blumer (1922a) as distinct from Erysiphe cichoracearum. As treated by him it is limited

to the Boraginaceae. Neger (1902) failed to transfer the mildew on Lithospermum arvense to Hieracium murorum, Symphytum tuberosum and Pulmonaria officinalis. The mildew on Anchusa officinalis did not infect Lycopsis arvensis or Echium vulgare. That from Echium vulgare could not infect Anchusa and Lycopsis. That from Pulmonaria officinalis did not infect Hieracium. Blumer (1922a) transferred the mildew on Symphytum officinale to Symphytum asperrimum, S. orientale, Cynoglossum officinale, Echinospermum lappula, Myosotis arvensis, Cerinthe major, C. alpina by direct inoculation, and to Lycopsis arvensis, Anchusa italica and Echium vulgare by the use of "bridging species". The mildew from Symphytum officinale did not infect Asperugo procumbens, Borago officinalis, Anchusa officinalis, Pulmonaria montana, Myosotis silvatica, M. scorpioides, Cerinthe minor and Echium violaceum. The mildew from Echium vulgare by direct inoculation infected Borago officinalis, Myosotis silvatica, M. sparsiflora, Cerinthe major, Echium rubrum, E. violaceum, E. plantagineum and Omphalodes linifolia, and by the intervention of a bridging species Cerinthe alpina was also infected. This mildew did not infect Symphytum officinale, Cynoglossum officinale, Anchusa officinalis, Pulmonaria montana and Cerinthe minor. The mildew on Myosotis silvatica infected M. stricta, M. sparsiflora, M. arvensis, Cerinthe major, Echium vulgare and E. violaceum, while infection failed on Symphytum officinale. The mildew on Pulmonaria montana infected only P. montana, Cerinthe major and Symphytum officinale, whereas Cynoglossum officinale, Lycopsis arvensis, Anchusa officinalis, A. italica, Myosotis silvatica, M. arvensis, Cerinthe minor and Echium vulgare were not infected. Cerinthe major, the only species tested against the mildew from Asperugo procumbens, was infected.

These data demonstrated that Cerinthe major was a favorable host for all these mildews. From these data Blumer (1933) established and named eight special forms of the borage mildew, each restricted to one or several genera or species of host plants. It should be noted that Blumer failed to get reciprocal infection with the mildews on Symphytum officinale and Pulmonaria montana and on S. officinale and Echium vulgare. He inoculated no species outside the Boraginaceae with these mildews. Bouwens (1927) failed to infect Lappa minor (Arctium minus) and Borago officinalis with the mildew on Symphytum officinale.

Neger (1902) and Blumer (1922b) demonstrated that among the few species of plants tested the mildew on Lactuca muralis was specialized to this species. The latter author also showed that Lactuca perennis and L. virosa, as well as Cichorium intybus, C. spinosum, Aposeris foetida, Hypochaeris glabra, Lapsana communis, Sonchus oleraceus and S. asper could be infected by the mildew on Dendroseris marginata.

Data for the mildew on cucurbits present a confusing situation. The mildew has been referred to several different species. The extremely rare occurrence of perithecia on these hosts usually makes precise identification impossible. In some cases, collections with perithecia have been referred to Erysiphe cichoracearum. Salmon(1900) treated the mildew on squash as E. cichoracearum.

Concerning the specialization of the cucurbit mildew, Reed (1907, 1908) showed it to be restricted primarily to the Cucurbitaceae, although Helianthus annuus and Plantago rugelii were reportedly infected by the mildew from Hubbard and Marblehead varieties of squash. In these two cases, however, the control plants also became infected, so the results are questionable. He found that Coccinea cordifolia, Luffa

acutangula and L. aegyptica were resistant to the cucurbit mildew, whereas Citrullus vulgaris, Cucumis anguria, C. dipsaceus, C. melo, Cucurbita foetidissima, C. maxima C. moschata, C. pepo, Cyclanthera explodens, Ecballium elaterium, Echinocystis lobata, Lagenaria vulgaris, Melothria scabra and Sicyos angulatus were susceptible. Whitaker and Pryor (1945) found that Cucumis metuliferus, Cucurbita palmata, C. foetidissima and Lagenaria leucantha were susceptible to the cucurbit mildew; Benincasa hispida, Bryonia dioica, Cucumis melo, C. sativus, Cucurbita pepo, C. maxima, C. ficicola, Echinocystis macrocarpa and Trichosanthes anguina were moderately susceptible; and that Citrullus vulgaris, Cucumis anguria, Cyclanthera explodens, C. pedata, Ecballium elaterium, Luffa acutangula and L. aegyptica possessed high resistance to the cucurbit mildew.

Miller and Barrett (1931) failed to get reciprocal infections with the mildews from cantaloupe and sunflower, Helianthus annuus. Miller (1938) infected reciprocally a cucurbit and papaya, Carica papaya, with the mildews on these two hosts.

There is a further specialization within the cucurbit mildew. Jagger et al (1938) reported the occurrence of two "biologic forms" of the mildew on cantaloupe, distinguished by the reaction of a variety of cantaloupe.

Hammarlund (1945) and Blumer (1950, 1952) have reported studies of a cucurbit mildew which they identify as Erysiphe polyphaga Hamm. This species is distinguished from E. cichoracearum by having 3- and 4-spored as well as mainly 2-spored asci, and a very wide range of hosts. Hammarlund transferred this mildew from Cucumis sativus to sixty-two of ninety-nine species from the Crassulaceae, Scrophularia-

ceae, Primulaceae, Saxifragaceae, Begoniaceae, Solanaceae, Cucurbitaceae, Labiatae, Linaceae, Compositae, Verbenaceae and Euphorbiaceae. Blumer (1950,1952) extended the host range of E. polyphaga by the addition of one species each from the Crassulaceae, Scrophulariaceae and Labiatae, and by Calluna vulgaris of the Ericaceae, Cissus antarctica of the Vitaceae, Myosotis sp cult. of the Boraginaceae, Saint-Paulia ionantha of the Gesneriaceae and Helianthus annuus and Scorzonera hispanica of the Compositae. Blumer also reported (1950) the reciprocal infection of Cucumis sativus and Helianthus annuus by their respective mildews. On account of these results he suggested that Reed had probably used E. polyphaga rather than E. cichoracearum in his experiments (1907,1908) with the cucurbit mildew.

A powdery mildew, identified as Erysiphe cichoracearum DC., has been reported on potato, Solanum tuberosum, by Ducomet (1920,1921), Deckenbach (1924), Jaczewski (1926), Müller (1928), Kunkel (1936), Valleau (1941) and Menzies (1950). Thomas (1946) reported cultural experiments in which he inoculated several species related to potato with conidia of the potato mildew. Infection occurred on potato and on Nicotiana tabacum, variety White Burley. No enumeration of the species and varieties employed in this study was given Valleau (1946) has reported a mildew on Nicotiana tabacum in the field. Hammerlund (1945) and Blumer (1950,1952) list tobacco, potato and tomato as hosts for Erysiphe polyphaga, each having been infected by the mildew from Cucumis sativus.

Marcelli (1949) published results of infection experiments with a powdery mildew from Nicotiana tabacum. He considered this mildew to be Erysiphe cichoracearum DC. although only known in the conidial

stage. He transferred this mildew to Cucurbita maxima, Citrullus vulgaris, Cucumis melo and C. sativus. He states that the same mildew occurred in the greenhouse on Cichorium intybus, Solanum tuberosum, S. melongena, Lycopersicum esculentum, Daturastramonium, Brassica oleracea, B. rapa and Ricinus communis.

Menzies (l.c.) found a mildew on Solanum nigrum, variety villosum which was morphologically indistinguishable from the potato mildew. He reported finding this weed heavily infected, growing intermingled with entirely healthy potato plants in the field. He concluded that the mildew on potato was a distinct "physiological race" as compared to the mildew on Solanum nigrum, var. villosum.

Mains (1942) presented evidence from field studies of selections of perennial phlox for the existence of several physiological forms of Erysiphe cichoracearum DC. distinguished by the reaction of certain varieties and selections of perennial phlox.

Circumstantial evidence has been presented by Deslandes et al (1953) for the occurrence of two biological races of Erysiphe cichoracearum on lettuce. They report the occurrence of perithecia of this mildew on both cultivated lettuce and on wild lettuce, Lactuca scariola. Earlier, Pryor (1941) had reported that the mildew on wild lettuce was not transferred to commercial varieties of cultivated lettuce in a series of infection experiments.

METHODS AND MATERIALS

I. Infection Experiments:

A. Cultures of Mildews Employed:

Mildews were obtained from the following sources:

1. Zinnia: In 1950-1951 the mildew was taken from zinnias in the vicinity of Milford, Michigan, and in 1951-1952 and 1952-1953 from plants at the Botanical Gardens of the University of Michigan.

2. Phlox: The mildew from infected perennial plants at the Botanical Gardens was used. An infected plant was divided, a division was potted, and taken into the greenhouse. Subsequently the mildew was transferred to Phlox drummondii, an annual, on which species it was carried thereafter.

3. Cucurbits: The mildew was derived from infected squash plants at the Botanical Gardens the first two years and from a cucurbit (Cucumis sativus), which became infected in the greenhouse during 1952-1953.

4. Cerinthe major: This mildew was represented by two accessions, one developed on C. major after inoculation with conidia of the zinnia mildew and the other was derived from a field infection of this species of host.

5. Inula helenium: One accession developed in the field and the other was obtained after inoculation with conidia of the zinnia mildew.

6. Helianthus annuus: One accession was derived from an infection on Russian Mammoth sunflowers in the field; the other accession was from plants infected with conidia of the zinnia mildew.

These cultures were maintained by subculturing to appropriate susceptible plants whenever necessary.

There are in the literature several reports of the occurrence of Erysiphe cichoracearum on the species of hosts used in this study. The mildews on cucurbits have been mentioned by Salmon (1900), Reed (1907,1908), Jørstad (1925), Miller and Barrett (1931), Blumer (1933, 1950,1952), Jagger et al (1938), Miller (1938), Hammarlund (1945) and Whitaker and Pryor (1945). The mildew on Cerinthe major was considered by Blumer (1933). The sunflower mildew was mentioned by Salmon (1900), Reed (1908), Miller and Barrett (1931), and Blumer (1950). Both Salmon (1900) and Blumer (1933) listed Inula helenium as a host for Erysiphe cichoracearum. Zinnia elegans was not treated by either Salmon or Blumer as a host for any mildew. The mildew on Z. elegans has been identified as E. cichoracearum by Le Clerg, E.L. (1930), Lenty, P.L. and Stevenson, J.A. (1948), Miles, L.E. (1935), Harrar, J.G. (1936), Miller, P.A. (1940), and several anonymous authors (1927, 1928,1929). The occurrence of perithecia of the mildew on Z. elegans is extremely rare. It is probable, therefore, that the above identifications were made without perithecia.

Salmon gives Phlox divaricata, P. drummondii, and P. paniculata as hosts for Erysiphe cichoracearum DC. Weiss (1950 et seq.) likewise lists Erysiphe cichoracearum DC. on Phlox. Blumer (1933) did not treat the mildew on species of Phlox.

There are no references in the literature to infection experiments performed with the zinnia mildew, or of any species of Zinnia being used as a host in infection experiments.

Other than the work of Mains (1942), whose investigations were

limited to Phlox, no investigations have been carried out to determine if hosts for the phlox mildew occur outside the genus.

B. Greenhouse Experiments:

At the outset of this investigation an attempt was made to obtain as many as possible of the species of hosts listed for Erysiphe cichoracearum in Salmon's monograph. Special attention was given to members of the Compositae, although not to the exclusion of species from other families. Subsequently additional host species were obtained to supplement the original selections. Most species were raised from seed. Baker and Locke (1946) have shown that zinnia seeds bearing perithecia did not produce mildew, and therefore apparently plants grown from seeds of mildewed plants were free of mildew. Since divisions or cutting of plants may carry infection it seemed best to utilize seedlings as far as possible.

Before experiments to determine the host specialization were attempted, a series of transfers of the cultures were made, each time using conidia from a well isolated conidial patch for the inoculum. After several such selective inoculations were made, the ultimate cultures were considered to be essentially single spore cultures on the assumption that any well isolated conidial patch had probably developed from a single conidium.

Reed (1915) has shown that any factors which produce increased vigor of the host plant will cause a correlated better development of the fungus. No attempt was made to control relative humidity in the greenhouse since this seems to be of little importance in the development of mildews according to the results of Duvdevani et al (1946) for the cucurbit mildew.

Throughout the course of the experiments light and temperature conditions were maintained as constant as possible under greenhouse conditions. The temperature of the room in which the plants were inoculated and incubated was kept at 60-70 degrees F. All plants were given supplementary light from a three-hundred Watt white light bulb until midnight throughout the short days of the winter months. The light bulb was suspended about four feet above the greenhouse benches. This extra light period each day simulated late summer or early fall conditions of about fifteen hours of light per day.

The host plants were usually inoculated at the two- or four-leaf stage although occasionally a more mature plant was inoculated to check for possible differences in susceptibility due to the age of the plant. In every experiment plants of the same species from which the conidia were taken were inoculated with the experimental plants to check the viability of the conidia.

Two methods of inoculation were utilized. During the earlier stages of the study a conidial suspension was atomized onto the leaves and cotyledons of the experimentsl plants. Aseptic conditions were maintained by rinsing the atomizer twice both in tap water and distilled water and allowing it to dry. This seemed sufficient in view of the short period of viability of the conidia of Erysiphe cichoracearum. Later dusting the conidia by lightly tapping infected leaves over previously moistened leaves was employed. Results showed that this method produced essentially the same degree of infection as did the former method. Accordingly, the simplier dusting method was adopted and used in all subsequent experiments.

The use of the dusting method introduced some possibility of

contamination of the control plants by air-borne conidia. To reduce this possibility and to provide checks, two groups of plants, one the control plants and the other the experimental plants, were placed in the inoculation chambers in the room containing the reserve of plants. Then they were transferred to the room where the mildew to be tested was maintained. The control chambers were not opened until the termination of the experiment, while the chambers with the experimental plants were opened and the inoculations carried out. The inoculation chambers used for the infection experiments were wood with glass for the roof, as described by Mains (1924).

Yarwood (1936) has shown that for conidia of Erysiphe cichoracearum from Helianthus the highest percentage of germination (24%) was obtained when the conidia were on the surface of water, whereas suspended in water there was only 13% germination. The bottom of each inoculation chamber was lined with Sphagnum moss which was moistened for each experiment to prevent excess evaporation of water from the surface of the plants. These germination data of Yarwood also favored the dusting method of inoculation over the conidial suspension method.

In each experiment the chambers were closed for 24–48 hours after inoculation and then were partially opened to allow for circulation of air. Three or four days after inoculation the experimental plants were removed from the chambers to the greenhouse benches. Observations were made usually on the fifth day after inoculation and were checked on the seventh, eighth or ninth day. The fifth day was chosen for initial observations since previous workers reporting on this mildew agree that infection will become evident by the fourth to sixth day after inoculation. The second observation was found necessary to

determine the correct reaction type. During 1952-1953, for some unknown reason, the incubation period was longer and therefore initial readings had to be delayed. It was rare for infection to be manifest in less than one week after inoculation.

Usually all seedlings of a species gave similar reactions when inoculated. In some instances one or more plants of otherwise susceptible species did not show infection when inoculated under optimal conditions. Such uninfected plants were re-inoculated. They also were placed in such a position on the greenhouse benches as to be continuously inoculated by air-borne conidia. Then if such plants did not develop mildew they were considered to be resistant.

The infection experiments reported here were carried out only during the winter months, generally from about the middle of October to the middle of May depending on the earliness or lateness of the season. This interval closely corresponds to the period when there is no conidial development of mildew in the field. This seasonal restriction is necessary since during the periods of active mildew development in the field wind blown spores are a constant source of contamination.

C. Field Experiments:

During the summer of 1951 field studies were undertaken with plants grown from twenty-nine lots of seed of zinnias which were obtained from Vaughan and Company, Chicago, Illinois, with the hope of finding resistant varieties or selections to the zinnia mildew. These included varieties and mixtures of varieties, the latter being employed in order to increase the possibilities of the discovery of resistance. Each seed lot was given an accession number; fifty seed-

lings of each number were planted in rows in the field.

An epiphytotic was created in the plantings by placing zinnia plants heavily infected with mildew in the rows. Development of the mildew was studied. Careful notation was made of any plant which either showed no infection or which was markedly late in becoming infected.

II. Morphological Studies:

Morphological studies were made in order to determine whether any correlations occur between host specialization and morphology. Studies of perithecia were carried out with material from the writer's collections and from materials in the University of Michigan Herbarium. The perithecia were mounted in Amann's medium (Johansen, 1940, p.313) with either cotton blue or acid fuchsin added as a stain. Measurements were made with an ocular micrometer at a magnification of approximately 430 diameters. Two hundred morphologically mature perithecia from each collection were measured wherever possible. The data from these measurements were treated statistically. Collections of Erysiphe cichoracearum in the University of Michigan Herbarium were checked for perithecial diameter. Collections of the species of mildew segregated by Blumer from E. cichoracearum sensu Salmon were also studied for perithecial diameter.

Data concerning the number of ascospores per ascus for each collection were obtained by exerting a slight pressure on the cover glass with a dissecting needle to rupture the perithecia. The asci were extruded from the perithecia in this manner.

No attempt was made to measure asci and ascospores of the mildews for statistical purposes. Although it is comparatively easy to

distinguish mature perithecia by the dark coloration, there is no such convenient criterion by which maturity of asci or ascospores can be determined. Salmon (1903) used discharged ascospores from naturally dehisced perithecia. Since ascospores are discharged only from over-wintered perithecia it was not feasible to use them in this study.

In the study of the conidia both fresh and herbarium materials were used. The fresh material was mounted in water and the herbarium material in Amann's medium. One hundred conidia of each collection were measured for both length and width. In all cases only abcissed completely free conidia were measured. For the fresh material only free vacuolate conidia were considered, the presence of vacuoles being indicative of maturity.

RESULTS

I. Greenhouse Experiments:

Data obtained from the infection experiments during this study are presented in Table IV. The different reaction types are graded on the following system:

0 - no infection evident macroscopically;
I - slight mycelial development with slight or no conidial production;
II - abundant development of mycelium with no or only slight conidial production;
III - mycelium and conidia developed abundantly.

Many of the tests with the different species of hosts were repeated several times throughout each year and from year to year. This was necessitated by the relatively restricted space available for the stock supply of plants to be inoculated and for the performance of the experiments. In each experiment several to many plants of the different species were inoculated.

A. Results with *Erysiphe cichoracearum* from *Zinnia elegans*:

As shown in Table IV forty-nine species of the Compositae were inoculated and infection occurred on the following: *Zinnia elegans*, *Z. pauciflora*, *Z. verticillata*, *Helianthus annuus*, *Arctium minus*, *A. nemorosum*, *Xanthium chinense*, *X. spinosum*, *X. strumarium*, *Mikania scandens*, *Inula helenium*, *Carlina acaulis*, *Lactuca perennis*, *Cosmos* sp., *Scorzonera hispanica*, *Crepis foetida*, *Felicia amelloides*, *Hieracium alpinum* and *H. prenanthoides*. Of these *Zinnia pauciflora* and *Z. verticillata* have not been reported previously as hosts for *Erysiphe cichoracearum*. Five species of Boraginaceae were inocu-

Table IV: Results of infection experiments with *Erysiphe cichoracearum* from various sources.

Host plants inoculated:	Reactions of the hosts to the mildews from:					
	Zinnia elegans	Inula helenium	Cerinthe major	Helianthus annuus	Phlox (cult.)	Cucurbita pepo
Compositae:						
Zinnia elegans	III (38)[1]	III (3)	III (4)	III (3)	0 (8)	0 (6)
	II (18)	II (2)	II (7)	I (3)		
Zinnia pauciflora	III (20)	-	II (18)	II (32)	-	-
Zinnia verticillata	III (12)	-	II (5)	II (26)	-	-
Prenanthes purpurea	0 (8)	-	-	0 (5)	0 (3)	-
Sonchus arvensis	0 (9)	-	-	-	0 (4)	0 (3)
Tanacetum vulgare	0 (3)	-	-	-	-	0 (1)
Helianthus annuus	III (5)	III (2)	II (10)	III (9)	0 (8)	0 (8)
	II (13)	II (2)	0 (2)			
Arctium minus	II (13)	-	II (5)	II (4)	0 (4)	0 (8)
Arctium nemorosum	II (15)	-	II (5)	II (6)	-	-
Taraxacum officinalis	0 (3)	-	-	-	0 (2)	0 (3)
Centaurea cyanus	0 (7)	0 (4)	-	0 (4)	-	-
Centaurea scabiosa	0 (4)	-	-	-	-	-
Centaurea dealbata	0 (4)	-	-	-	-	-
Centaurea jacea	0 (11)	-	-	-	0 (5)	-
Centaurea macrophylla	0 (2)	-	-	-	0 (4)	-
Centaurea melitensis	0 (33)	-	0 (18)	0 (12)	-	-
Xanthium chinense	III (9)	-	-	-	-	0 (2)
	0 (3)					
Xanthium spinosum	III (1)	-	-	-	0 (4)	0 (2)
	II (8)					
Xanthium strumarium	II (3)	-	-	-	-	-

1. The number in parenthesis is the number of plants giving the reaction.

Table IV: Continued:

Host plants inoculated:	Reactions of the hosts to the mildew from:					
	Zinnia elegans	Inula helenium	Cerinthe major	Helianthus annuus	Phlox (cult.)	Cucurbita pepo
Compositae: (continued)						
Mikania scandens	III (1)	-	-	-	-	-
	II (17)					
	0 (4)					
Cichorium intybus	0 (18)	0 (7)	0 (7)	0 (5)	-	-
Carduus acanthoides	0 (10)	-	-	-	0 (3)	-
Carduus mutans	0 (6)	-	-	-	0 (4)	-
Rudbeckia hirta	0 (5)	-	-	-	-	-
Calendula officinalis	0 (12)	0 (6)	0 (8)	0 (5)	0 (4)	0 (2)
Lapsana communis	0 (6)	-	-	-	0 (4)	-
Eupatorium cannabinum	0 (10)	-	-	-	0 (5)	0 (2)
Hieracium alpinum	III (23)	-	III (24)	0 (20)	-	-
Hieracium amplexicaule	0 (16)	-	0 (10)	0 (10)	-	-
Hieracium murorum	0 (5)	-	0 (3)	-	0 (4)	0 (2)
Hieracium pilosella	0 (16)	0 (5)	0 (9)	0 (7)	-	-
Hieracium prenanthoides	III (19)	-	III (18)	0 (16)	-	-
Hieracium silvaticum	0 (12)	-	-	0 (8)	-	-
Inula helenium	III (8)	III (3)	III (1)	I (7)	0 (3)	-
	II (12)		I (3)	0 (1)		
Carlina acaulis	II (3)	-	I (3)	0 (1)	-	-
Achillea millefolium	0 (16)	-	0 (4)	-	0 (3)	0 (5)
Cirsium vulgare	0 (10)	-	-	-	-	-
Cirsium arvense	0 (2)	-	-	-	0 (3)	0 (3)
Cirsium canum	0 (4)	-	-	-	-	-
Artemisia absinthium	0 (11)	0 (5)	0 (6)	0 (5)	-	-
Artemisia vulgaris	0 (7)	0 (6)	0 (7)	0 (6)	-	-
Lactuca perennis	II (14)	0 (7)	0 (21)	II (16)	-	-
	0 (4)			0 (7)		
Dahlia sp. (annual)	0 (1)	-	-	-	0 (2)	-

Table IV: Continued:

Host plants inoculated:	Reactions of the hosts to the mildews from:					
	Zinnia elegans	Inula helenium	Cerinthe major	Helianthus annuus	Phlox (cult.)	Cucurbita pepo
Compositae: (continued)						
Cosmos sp.	III (3) II (10)	-	II (5)	III (3) II (10)	-	-
Helichrysum bracteatum	0 (10)	0 (5)	0 (8)	-	-	-
Aster alpinus	0 (16)	-	-	0 (5)	-	-
Scorzonera hispanica	III (8) II (6)	-	II (8)	II (8)	-	-
Crepis foetida	II (22)	-	II (22)	II (4)	-	-
Felicia amelloides	II (32)	-	II (20)	-	-	-
Cucurbitaceae:						
Cucurbita pepo (CP 434 A1)	0 (4)	-	-	-	0 (6)	III (12)
(25-5XX)	0 (4)	-	-	-	0 (5)	III (4)
(Zuccini X White Disk)	-	-	-	-	-	III (3)
(Conn. Field Pumpkin)	0 (6)	0 (5)	0 (2)	0 (5)	-	II (1)
Cucurbita maxima	0 (5)	0 (2)	0 (4)	0 (6)	-	II (3)
Cucurbita melanosperma	0 (3)	-	0 (2)	0 (5)	-	-
Echinocystis lobata	0 (3)	-	-	-	-	II (3)
Sicyos angulatus	-	-	-	-	-	II (3)
Cyclanthera pedata	0 (4)	0 (2)	0 (3)	0 (4)	-	-
Momordica charanthia	0 (3)	0 (4)	0 (5)	0 (2)	-	0 (4)
Citrullus calycanthidis	0 (3)	-	0 (6)	0 (4)	-	-
Bryonia dioica	0 (4)	-	0 (4)	0 (7)	-	0 (6)
Solanaceae:						
Hyoscyamus niger	0 (15)	0 (5)	0 (15)	0 (15)	-	-
Salpiglossis sinuata	II (15) 0 (1)	-	I (5)	I (5)	-	-
Nicotiana tabacum	0 (19)	-	0 (10)	0 (10)	-	-

Table IV: Continued:

Host plants inoculated:	Reactions of the hosts to the mildews from:					
	Zinnia elegans	Inula helenium	Cerinthe major	Helianthus annuus	Phlox (cult.)	Cucurbita pepo
Boraginaceae:						
Symphytum officinale	0 (17)	-	0 (25)	0 (10)	0 (2)	0 (1)
Anchusa italica	0 (2)	-	-	-	0 (2)	0 (1)
Cerinthe major	III (5)	II (4)	III (11)	III (2)	0 (3)	-
	II (18)	I (1)	II (6)	II (3)		
Cerinthe minor	0 (5)	-	0 (10)	0 (9)	-	-
Cynoglossum officinale	0 (5)	-	0 (5)	-	-	-
Plantaginaceae:						
Plantago alpina	0 (13)	-	0 (5)	0 (10)	-	-
Plantago coronopus	0 (16)	-	-	0 (6)	-	-
Plantago lanceolata	0 (12)	-	0 (11)	0 (7)	0 (3)	-
Plantago major	0 (4)	-	-	0 (16)	0 (3)	0 (4)
Plantago maritima	0 (11)	0 (8)	0 (8)	0 (4)	0 (3)	-
Plantago media	0 (10)	0 (6)	0 (7)	0 (9)	-	-
Plantago rugelii	0 (12)	-	-	0 (13)	0 (4)	0 (9)
Polemoniaceae:						
Phlox sp.(cult. perennial)	-	-	-	-	III (4)	-
Phlox drummondii	0 (15)	-	0 (5)	0 (5)	III (14)	0 (4)
					0 (1)	
Cobaea scandens	0 (2)	-	-	-	0 (4)	0 (4)
Polemonium van-bruntiae	0 (2)	-	-	-	0 (3)	-
Polemonium flavum	0 (14)	0 (4)	0 (6)	0 (4)	-	-
Polemonium pauciflorum	0 (8)	-	-	0 (3)	-	-
Polemonium carneum	0 (15)	-	-	-	-	-
Gilia rubra	0 (10)	-	0 (4)	0 (4)	-	-
Navarretia squarrosa	0 (10)	-	0 (8)	0 (7)	-	-
Collomia abrotanifolia	0 (8)	-	-	-	-	-

Table IV: Continued:

Host plants inoculated:	Reactions of the hosts to the mildews from:					
	Zinnia elegans	Inula helenium	Cerinthe major	Helianthus annuus	Phlox (cult.)	Cucurbita pepo
Labiatae:						
Teucrium chamaedrys	0 (2)	-	-	-	-	0 (1)
Prunella vulgaris	0 (4)	-	-	-	-	0 (4)
Salvia glutinosa	0 (1)	-	-	-	0 (3)	-
Stachys palustris	0 (5)	-	-	-	0 (4)	0 (3)
Scrophulariaceae:						
Antirrhinum majus	0 (22)	-	0 (6)	0 (4)	-	-
Verbascum nigrum	0 (14)	0 (5)	0 (8)	0 (6)	-	-
Verbascum thapsus	0 (17)	-	0 (4)	0 (9)	-	-
Violaceae:						
Viola sp. (cult.)	0 (2)	-	-	-	-	0 (2)
Cruciferae:						
Cardamine impatiens	0 (16)	-	0 (10)	0 (5)	-	-
Rubiaceae:						
Galium aparine	0 (30)	-	0 (12)	0 (14)	-	-

lated, only Cerinthe major becoming infected. Three species of the Solanaceae were inoculated; infection occurred on Salpiglossis sinuata. This represents the first report of E. cichoracearum on the genus Salpiglossis. The mildew was also inoculated onto ten species or varieties of the Cucurbitaceae, seven species of the Plantaginaceae, nine species of the Polemoniaceae, four species of the Labiatae and one species each of the Violaceae, Cruciferae and Rubiaceae, on all of which infection failed.

The mildew from the infections on Xanthium chinense, X. spinosum, Arctium minus, A. nemorosum, Lactuca perennis, Felicia amelloides, Cosmos sp., Zinnia pauciflora and Z. verticillata were successfully transferred back to Zinnia elegans. The mildew obtained from Arctium minus was also successfully transferred to Helianthus annuus and Cerinthe major.

In the following otherwise susceptible species resistant plants were found: Xanthium chinense, three of twelve plants; Mikania scandens, four of twenty-two; Lactuca perennis, four of eighteen plants; Crepis foetida, ten of thirty-two plants; and Salpiglossis sinuata, one of thirteen plants.

B. Results with Erysiphe cichoracearum from Inula helenium:

This mildew was tested on eleven species of the Compositae, infection occurring only on Inula helenium, Zinnia elegans and Helianthus annuus. Four species or varieties of cucurbits were tested, infection failing in all cases. Of the Boraginaceae only Cerinthe major was tested, the inoculation resulting in infection of this species. Two species of the Plantaginaceae and one each from the

Polemoniaceae, Scrophulariaceae and Solanaceae were inoculated without successful infection.

C. Results with Erysiphe cichoracearum from Cerinthe major:

As shown in Table IV twenty-five species of the Compositae were inoculated with this mildew; infection occurred on Zinnia elegans, Z. pauciflora, Z. verticillata, Helianthus annuus, Arctium minus, A. nemorosum, Hieracium alpinum, H. prenanthoides, Inula helenium, Cosmos sp., Scorzonera hispanica, Crepis foetida and Felicia amelloides. Seven species or varieties of cucurbits were tested, infection failing in all cases. Four species of the Boraginaceae were inoculated with this mildew, only Cerinthe major becoming infected. Four species each of the Plantaginaceae and Polemoniaceae, three species of the Scrophulariaceae and one from the Violaceae were inoculated without successful infection. Three species of the Solanaceae were inoculated, only Salpiglossis sinuata proving susceptible.

Cerinthe major is listed by Salmon (1900) as a host for Erysiphe cichoracearum, while Blumer (1922a) cites it as a host for E. horridula. No perithecia developed on this host during this investigation, so its specific determination was not definitely established. The original culture of this mildew was obtained from the field in the summer of 1952. The plants were growing next to zinnias which were heavily infected with Erysiphe cichoracearum. Because of this proximity to plants heavily infected with E. cichoracearum, and because the host relationships of the mildew on Cerinthe major are similar to those of the mildew from zinnias, the mildew on C. major appears to be E. cichoracearum. The original accession of the mildew on

C. major, derived from a field infection of this host, reacted identically with an accession obtained after infection of C. major with conidia of the mildew on zinnia.

D. Results with E. cichoracearum from Helianthus annuus:

This mildew from sunflower has been tested against twenty-one species of the Compositae; infection occurred on Helianthus annuus, Zinnia elegans, Z. pauciflora, Z. verticillata, Arctium minus, A. nemorosum, Inula helenium, Lactuca perennis, Cosmos sp., Scorzonera hispanica and Crepis foetida. In the Boraginaceae Symphytum officinale, Cerinthe major and C. minor were inoculated, C. major being the only species infected. Seven species or varieties of the Cucurbitaceae were tested with negative results. Seven species of Plantago were inoculated without infection. Five species of the Polemoniaceae were tested, infection failing in all cases. Three species each of the Scrophulariaceae and the Solanaceae and one each from the Violaceae and Rubiaceae were inoculated with infection occurring only on Salpiglossis sinuata of the Solanaceae.

During the winter of 1951-52 these tests were carried out with an accession obtained after infection of this species with conidia of the zinnia mildew. Another accession was obtained from the field during the summer of 1952, which was used for the tests during 1952-53. Only the second accession of this mildew was tested on Cerinthe major and Inula helenium. The accession from the field was identified as E. cichoracearum by perithecial characteristics.

Table IV shows that seven plants of Lactuca perennis of the twenty-three inoculated with the mildew from sunflower were not

infected. Similarly one plant of Inula helenium was not infected, whereas seven other plants were infected.

E. Results with E. cichoracearum from perennial phlox:

This mildew was inoculated onto nineteen species of the Compositae, two selections of Cucurbita pepo, three species of the Boraginaceae, four species of the Plantaginaceae, two species of the Labiatae and four species of the Polemoniaceae, with infection occurring only on Phlox drummondii and the cultivated perennial phlox. In the case of P. drummondii one plant of fifteen did not become infected with this mildew. Viable seed could not be obtained from this plant. Mains (1942) has found that both the perennial phlox and P. drummondii vary in their reaction to the mildew and has reported resistant selections.

F. Results with E. cichoracearum from cucurbits:

The results with the two accessions of this mildew are enumerated separately since the accessions were obtained from different species of the Cucurbitaceae. The accession of this mildew obtained from Cucurbita pepo infected in the field gave infection on the following: Cucurbita pepo, selections CP 434 A 1, 25-5XX and Zuccini X White Disk, Echinocystis lobata and Sicyos angulatus. Thirteen species of the Compositae, three species of the Labiatae, two species each of the Boraginaceae, Plantaginaceae and Polemoniaceae, and one species of the Violaceae were also inoculated with this mildew without infection occurring. The second accession of the cucurbit mildew, which developed on Cucumis sativus in the greenhouse, was used to inoculate

Cucurbita pepo, variety Connecticut Field Pumpkin, Cucurbita maxima, Momordica charanthia and Bryonia dioica. Infection occurred on Cucurbita maxima and C. pepo, variety Connecticut Field Pumpkin, whereas no infection developed on M. charanthia and B. dioica.

Several different mildews have been reported on the Cucurbitaceae, namely Erysiphe cichoracearum (Salmon, 1900; Reed, 1907,1908; Jørstad, 1925); E. polygoni (Salmon, ibid.); E. polyphaga (Hammarlund, 1945; Blumer, 1950, 1952); Sphaerotheca fuliginea (Blumer, 1933); S. "Castagnei" (Salmon, ibid.) and Oidium sp. (various authors). Since no perithecia developed on members of the Cucurbitaceae in my experiments an exact identification of the fungus was not possible. Some of the collections reported by Salmon (1905, p. 249) and Reed (1907, p. 533) bore perithecia of Erysiphe cichoracearum. Also, on the basis of conidial measurements Bouwens (1924, p. 22) decided the mildew on cucurbits was E. cichoracearum.

II. Field Studies:

In species of hosts which are variable in their reaction to mildew it is possible to develop resistant strains by selection. In Phlox drummondii, an annual cultivated phlox, and the perennial phlox, Mains (1942) reported selections resistant to the phlox mildew. Resistant varieties of cantaloupe have been developed by other investigators. As previously stated, plants resistant to the zinnia mildew were found in the otherwise susceptible species, Xanthium chinense, Mikania scandens, Lactuca perennis, Crepis foetida and Salpiglossis sinuata. There seems to be some evidence that re-

sistance might be found in zinnia of which the mildew is an important disease. To study the possibility of resistance in zinnia a large number of plants was inoculated in the field by the methods already described. A summary of the varieties and strains of Zinnia elegans used for this study and of the percentages of the different reaction types shown by each is presented in Table V.

Under the epiphytotic conditions of this experiment in the field most plants were severely infected, usually all leaves were completely covered with mycelium and conidia and the flowering heads were also heavily infected. There was heavy conidial production on some infected heads, particularly those on which infection appeared early and spread rapidly over the entire plant. No perithecia of the mildew developed on the plants in the field.

Two months after the first appearance of infection on the varieties and strains on Zinnia only six plants in five accessions were not infected. These plants were: 2-31[2], 9-2, 14-8, 22-20, 23-21 and 23-26. Two weeks later these plants had also become infected and soon exhibited conidial production nearly equivalent to other plants of the accession. It is probable that under normal field conditions without the created epiphytotic these plants would not have shown much of any infection. Because of the early freedom from infection these six plants were the first selected as parents for the selfs in each accession and for the crosses made in accession 23.

Plants to act as parents were selected according to the mildew reaction recorded during the preliminary readings. The controlled pollinations were made by dusting pollen from matured staminate florets

2. The first number is the accession, the second the selection number.

Table V: Reactions of varieties and strains of *Zinnia* to *Erysiphe cichoracearum* under epiphytotic conditions in the field.

Variety or strain name:	Accession number:	No. of plants inoculated:	Percent. of reaction types II	III
Dahlia-flowered Mixed	1	48	6.3	93.7
Lilliput Tom Thumb Mixture	2	45	0	100
Indian Summer Mixture	3	50	0	100
Special Mixture All Types	4	49	2.0	98.0
Special Mixture All Giant Types	5	49	4.0	96.0
Lilliput Pastel Mixture	6	50	0	100
Peppermint Stick Mixed	7	45	0	100
Navajo Mixed	8	49	0	100
Midget Mixed	9	37	0	100
California Giants, Special Mixture	10	50	0	100
Pumila Double Mixed	11	50	8.0	92.0
Scabiosa-flowered Mixed	12	50	2.0	98.0
Cupid Mixed	13	50	4.0	96.0
Lilliput Vaughan's Special Mixed	14	48	2.1	97.9
Fantasy Mixture	15	50	2.0	98.0
Super Giants, Vaughan's Special Mixture	16	49	16.3	83.7
Gold Medal Mixture	17	49	4.1	95.9
Super Crown of Gold, Pastel Tints	18	49	2.0	98.0
Floradale Scarlet	19	43	0	100
Giant David Burpee[3]	20	15	0	100
Red Riding Hood	21	49	0	100
Spun Gold	22	48	0	100
Watermelon Pink	23	48	0	100
Royal Purple	24	48	0	100
Illumination	25	49	0	100
Polar Bear	26	49	2.0	98.0
Crimson Monarch	27	49	0	100
Eldorado	28	50	4.0	96.0
Oriole	29	47	0	100

3. Seed germination in this variety was very poor. Of the eighteen seedlings obtained, only six were healthy, the others having highly contorted leaves.

over the pistillate florets, the flowering heads having been bagged prior to the maturation of any of the florets of the head. It was found that the stamens of the heads matured before the pistils did; for this reason heads to be used for the female parent were not emasculated prior to bagging. Becquerel (1911) states in regard to the fertility of zinnias that he was able to obtain viable seeds from selfed florets, although cross-fertilization is the rule in zinnias. Self-fertilization was therefore not entirely eliminated in the plants which were crossed.

Seeds of eleven crosses and six selfs were collected. This was less than one-fourth the total number of pollinations made. The seeds of only seven crosses and three selfs germinated. In all cases too few plants were obtained to furnish a basis for any valid conclusions. The number of plants in each progeny can be determined from Table VI, which gives the results of the inoculation of the progenies of the crosses and selfs with the zinnia mildew. In Table VI the reactions of each type are the same as the system used for the infection experiments, previously given. In the cross, 16-9 X 16-15, and the self, 7-20, the first seven plants of the offspring were tested as seedlings in the greenhouse during the winter, 1951-52. The remainder of the progenies of each mating were tested as mature plants in the field during the summer, 1952.

The results suggest that resistant strains of zinnia may be obtained by continued selection, although no pronounced resistance was obtained in this study. A continuation of this line of experimentation did not seem justified in the present investigation.

Table VI: Reactions of the progenies of crosses and selfs of *Zinnia elegans* to the zinnia mildew.

Selfs and Crosses:	Number of plants in each progeny:	Reaction type to mildew:
13-9 selfed (III)[4]	1	I
14-8 selfed (III)	2	II
7-20 selfed (III)	20	III
11-37 (III) X 11-36 (III)	1	II
11-32 (II) X 11-38 (III)	1	II
	1	III
21-43 (III) X 21-50 (III)	3	II
16-44 (II) X 16-9 (II)	1	I
	2	III
16-9 (II) C 16-15 (III)	4	II
	11	III
	1	II
2-39 (III) X 2-38 (III)	1	II
	7	III
9-41 (II) X 9-42 (III)	3	I
	4	II
	11	III

4. The number in parenthesis is the type of reaction of the parent.

III. Morphological Studies:

Morphological studies were undertaken to determine whether variations in morphology are correlated with differences in host specialization. The herbarium material was studied with several objectives in mind. The first was to examine perithecia on species to which the writer had transferred the several mildews. Second, the collections on other families of hosts given by Salmon were examined. And third, collections determined as Erysiphe artemisiae, E. lamprocarpa, E. depressa, E. valerianae and E. horridula in the University of Michigan Herbarium were also studied.

Table VII gives the results of the study of perithecial diameter. The means for perithecia from collections of Erysiphe cichoracearum sensu Salmon are rather uniform, varying from 94.48 microns for a collection on Madia dissitifolia to 128.90 microns for a collection on Artemisia vulgaris. A collection on Chelone glabra of the Scrophulariaceae had exceptionally large perithecia, the mean being 141.74 microns. Excluding the Chelone glabra collection the means for all other collections make an almost perfect continuum from the 94.48 to 128.9 microns. The uniformity in perithecial size for these collections is more pronounced when we consider the ranges for the different collections. The collections on Madia dissitifolia, Helianthus sp. (specimen 49) and Valeriana officinalis had the smallest perithecia, with a range of 76.5 to 114.75 microns. Several collections had 78.7 microns as the smaller diameter with the larger perithecial diameters of these collections being from 131.0 to 157.3 microns. The range in size for the Chelone glabra collection was 114.75 to 175.95 microns. Salmon (1900) gives the range in perithecial size

Table VII: Results of the measurements[5] of perithecia from collections of Erysiphe cichoracearum sensu Salmon.

Host Plants:	Specimen[6]:	Mean, microns:	Standard deviation, microns:	Range, microns:
Compositae:				
Zinnia elegans	1	114.27	17.35	78.7-157.3
	2	115.84	12.1	78.7-157.3
	3	118.46	9.55	99.45-137.7
Ambrosia artemisiifolia	4	101.26	9.75	78.7-131.0
	5	101.29	3.44	78.7-137.7
	6	101.92	2.94	78.7-131.0
	7	103.1	3.3	78.7-137.7
	8	107.15	2.68	78.7-131.0
	9	113.2	2.85	78.7-137.7
	10	111.69	9.95	91.7-141.0
	11	115.78	9.77	91.8-145.35
Ambrosia trifida	12	100.75	7.1	84.15-114.75
	13	106.87	7.61	84.15-130.05
	14	109.15	8.72	91.8-130.05
	15	109.47	8.22	91.8-137.7
	16	98.76	6.13	84.15-107.1
Xanthium chinense	17	112.74	10.08	91.7-141.0
		106.07	9.05	91.8-130.05
	18	109.23	9.17	91.7-141.0
		111.07	9.38	91.8-137.7
	19	108.94	9.49	84.6-148.1
		106.99	8.01	91.8-130.05
	20	107.32	8.8	91.8-130.05
Arctium minus	21	116.39	9.02	99.45-137.7
	22	113.25	7.92	99.45-137.7
	23	106.01	7.43	91.8-122.4
	24	110.45	8.29	91.8-137.7
	25	115.86	9.83	91.8-137.7
Arctium majus	26	120.99	10.84	91.8-153.0
Arctium tomentosum	27	114.81	9.21	91.8-137.7
Tragopogon procifolius	28	112.53	9.69	91.8-145.35
Tragopogon pratensis	29	111.63	8.27	91.8-130.05
Scorzonera hispanica	30	110.74	8.06	91.8-137.7
Grindelia perennis	31	124.08	11.18	107.1-160.65
Vernonia fasciculata	32	111.77	8.91	91.8-137.7
	33	111.38	9.2	91.8-137.7
Lactuca integrata	34	109.24	7.8	91.8-130.05
Lactuca spicata	35	106.59	8.28	91.8-130.05

5. If possible, 200 perithecia from each collection were measured.
6. The numbers used in this column refer to the numbers in the Appendix, where information concerning the identity of the specimens will be found.

Table VII: Continued:

Host Plants:	Specimen:	Mean, microns:	Standard deviation, microns:	Range, microns:
Compositae (continued)				
Lactuca scariola	36	110.7	7.88	91.8-130.05
Chrysothamnus pumilus	37	117.9	12.81	99.45-168.3
Achillea ptarmica	38	112.55	8.69	99.45-137.7
Madia dissitifolia	39	94.48	8.3	76.5-114.75
Sonchus arvensis	40	110.24	9.83	91.8-137.7
Lygodesmia juncea	41	112.15	7.97	91.8-137.7
Iva xanthifolia	42	113.06	9.41	99.45-145.35
	43	115.75	8.77	99.45-153.0
Eupatorium purpureum	44	115.56	9.91	91.8-137.7
		110.93	10.27	91.8-145.35
Eupatorium ageritoides	45	115.67	14.66	84.15-153.0
Eupatorium cannabinum	46	104.78	7.18	84.15-122.4
Eupatorium perfoliatum	47	109.09	8.35	91.8-130.05
Helianthus sp.	48	108.07	6.95	91.8-130.05
	49	95.95	8.74	76.5-114.75
Helianthus tuberosus	50	111.88	9.36	91.8-137.7
	51	111.95	10.7	84.6-148.1
	52	106.33	9.08	91.7-141.0
Helianthus annuus	53	112.07	7.85	99.45-130.05
		115.43	7.58	99.45-137.7
"Hebanthun sp."	54	104.58	8.24	84.15-122.4
Aster fluviatilis	55	121.71	13.39	107.1-168.3
Aster azureus	56	98.69	8.53	84.15-122.4
Aster crassulus	57	121.1	9.15	99.45-145.35
Gutierrezia sarothrae	58	116.97	8.26	91.8-145.35
Artemisia vulgqris	59	128.9	14.85	99.45-168.3
	60	111.97	9.57	91.8-137.7
	61	109.97	8.31	84.15-130.05
	62	113.14	10.5	91.8-145.35
Solidago sp.	63	107.64	8.25	84.15-122.4
Senecio nemorensis	64	112.9	10.26	91.8-137.7
Hieracium sp.	65	114.21	9.81	91.8-137.7
Dyssodia papposa	66	101.85	7.03	84.15-122.4
Prenanthes purpurea				
Labaatae:				
Scutellaria latifolia	67	107.35	7.58	91.8-130.05
Stachys palustris	68	117.35	12.06	91.8-153.0
Lycopus europaeus	69	106.87	7.76	91.8-130.05
Valerianaceae:				
Valeriana furfurescens	70	105.87	6.09	91.8-122.4
Valeriana edulis	71	108.58	6.53	91.8-122.4
Valeriana officinalis	72	95.95	7.84	76.5-114.75
Hydrophyllaceae:				
Hydrophyllum fendleri	73	104.64	8.31	84.15-130.05

Table VII: Continued:

Host Plants:	Specimens:	Mean, microns:	Standard deviation, microns:	Range, microns:
Hydrophyllaceae (cont.)				
Nemophila menziesii	74	108.71	7.75	91.8-137.7
Boraginaceae:				
Hackelia californica	75	112.37	9.48	91.8-145.35
Cynoglossum officinale	76	109.55	9.04	91.8-137.7
Symphytum tuberosum	77	106.74	7.91	91.8-130.05
	78	112.31	9.51	91.8-145.35
Symphytum officinale	79	118.66	10.29	91.8-145.34
	80	107.98	7.86	91.8-130.05
	81	114.55	10.36	91.8-137.7
Mertensia lanceolata	82	108.25	9.39	91.8-130.05
Mertensia ciliata	83	114.32	6.84	91.8-130.05
Lappula californica	84	113.93	10.01	91.8-145.35
Plantaginaceae:				
Plantago rugelii	85	108.25	8.27	91.8-130.05
	86	100.91	8.98	84.15-122.4
Plantago major	87	108.63	9.12	91.8-130.05
Euphorbiaceae:				
Pyrrocoma lanceolata	88	113.07	8.53	91.8-137.7
Polemoniaceae:				
Polemonium albiflorum	89	105.42	7.28	91.8-122.4
Perennial phlox	90	115.28	12.6	78.7-144.2
	91	110.74	9.95	78.7-131.0
	92	115.29	11.63	78.7-157.3
	93	115.15	14.31	78.7-157.3
	94	102.97	3.24	78.7-131.0
	95	109.2	2.67	78.7-131.0
	96	116.9	3.47	84.6-162.2
	97	101.1	3.18	84.6-134.0
	98	108.3	2.72	84.6-134.0
	99	104.99	7.61	91.8-130.05
	100	113.03	10.36	84.15-137.7
	101	110.59	9.13	91.8-130.05
Polygonaceae:				
Eriogonum giganteum	102	112.91	8.18	91.8-137.7
Eriogonum blissianum	103	125.1	12.12	91.8-153.0
Malvaceae:				
Napaea dioica	104	102.43	8.65	84.15-122.4
Scrophulariaceae:				
Chelone glabra	105	141.74	14.1	114.75-175.95

Table VII: Continued:

Host Plants:	Specimens:	Mean, microns:	Standard deviation, microns:	Range, microns:
Urticaceae:				
Parietaria pennsylvanica	106	112.0	8.42	91.8-145.35
Verbenaceae:				
Verbena urticiaefolia	107	104.52	8.62	84.15-122.4
	108	104.88	8.82	84.15-130.05
Verbena stricta	109	107.61	7.56	91.8-130.05
Rubiaceae:				
Galium aparine	110	110.0	9.05	91.8-137.7
	111	123.28	10.33	107.1-160.65

as 80 to 140 microns, occasionally 140 to 180 microns. The results obtained in this study essentially are within the limits placed on perithecial diameter for E. cichoracearum by Salmon.

When the results are considered according to the family of the host plant, the following is found: for sixty-five collections on the Compositae a range in mean perithecial diameter of 94.48 to 128.9 microns; for thirteen collections on the Polemoniaceae, 101.1 to 116.9 microns; for three collections on the Labiatae, 106.87 to 117.35 microns; for three collections on Valeriana, 95.95 to 118.58 microns; for three collections on Plantago, 100.91 to 108.63 microns; for seven collections on Boraginaceae, 106.74 to 118.66 microns; for two collections on Hydrophyllaceae, 104.74 to 108.71 microns; for two collections on Polygonaceae, 112.91 to 125.11 microns; for three collections on Verbena, 104.52 to 107.61 microns; for one collection on Malvaceae, 102.43 microns; for one on Scrophulariaceae, 141.74 microns; for one on Urticaceae, 112.0 microns; and for two on Rubiaceae, 110.0 to 123.28 microns.

Blumer (1933) made rather extensive use of the color of the appendages of the perithecia and of the length of the appendages as diagnostic characteristics for species. Appendage coloration of the material in all collections of Erysiphe cichoracearum sensu Salmon observed by the writer was noted. Most collections were found to have perithecia with both hyaline and brown appendages. In some instances browned and hyaline appendages were found on the same perithecium. The appendages of E. cichoracearum are interwoven with the adjacent mycelium, so much so in many cases as to appear as a subiculum about the base of the perithecium. Even the most careful tech-

niques of dissection of the perithecium from the subiculum did not prove satisfactory. Most or all of the appendages were broken, as evidenced by their sharply angled distal ends. This makes it difficult to determine accurately the length of the appendages.

Blumer (1922a) separates Erysiphe horridula from E. cichoracearum sensu Salmon on the basis of E. horridula having 2-, 3-, and 4-spored asci in contrast to the 2-spored asci of E. cichoracearum. Hammarlund described Erysiphe polyphaga (1945), also distinguished from E. cichoracearum on the same basis, E. polyphaga having 2-, 3-, and 4-spored asci whereas E. cichoracearum has only 2-spored asci. In most collections the writer found from 78.5 to 95% of the asci to be 2-spored; from 5 to 21.5% of the asci observed were 3-spored; from 0.5 to 1.5% of the asci contained four spores In only three collections were the asci exclusively 2-spored. Two of these wholly 2-spored collections were on Arctium minus and had been identified as Erysiphe depressa, which Blumer (1933) gives as having only 2-spored asci. The third collection was on Senecio nemorensis, which Blumer gives as a host for E. cichoracearum sensu Blumer.

The abundance of the conidial stage of powdery mildews in comparison to the relative scarcity of perithecia on certain hosts has prompted several workers to attempt to use conidial morphology as a more important criterion for identifying powdery mildews. Table VIII presents the results for the measurement of 100 conidia of the mildews on Zinnia elegans, Cerinthe major, Inula helenium and Helianthus annuus from both fresh material mounted in water and herbarium material mounted in Amann's medium, and for conidia of the cucurbit and phlox mildews from herbarium material.

Table VIII: Results of measuring conidia[7] from certain collections of *Erysiphe cichoracearum* sensu Salmon.

Conidia from:	Specimen[8]:	Length: Range, µ:	Mean, µ:	S.D., µ:	Width: Range, µ:	Mean, µ:	S.D., µ:
Zinnia elegans	2	25.1-39.6	32.6	2.7	12.6-19.8	14.0	2.0
	112	21.6-37.8	31.5	2.6	12.6-19.8	14.0	1.9
	1	23.4-39.6	32.2	2.9	10.8-18.0	14.3	1.5
	113	21.6-37.8	30.4	2.8	10.8-18.0	14.7	1.4
	114	21.6-37.8	31.3	2.5	10.8-19.8	13.6	1.5
	115	23.4-41.4	32.3	2.6	10.8-19.8	15.4	1.8
Cerinthe major	116	25.2-43.2	39.0	4.4	12.6-21.6	17.8	1.7
		27.0-43.2	36.0	2.9	10.8-21.6	17.0	1.9
	117	27.0-43.2	36.9	3.1	10.8-21.6	17.9	1.8
Inula helenium	118	27.0-43.2	36.1	2.6	10.8-21.6	18.0	1.8
Helianthus annuus	119	28.8-41.4	34.6	2.1	10.8-19.8	14.7	1.3
		28.8-45.0	37.6	2.6	12.6-23.4	18.0	1.9
Cucurbita pepo	120	23.4-37.8	31.0	2.1	10.8-18.0	14.4	1.0
		23.4-37.8	30.5	2.1	10.8-18.0	14.6	1.1
Cucurbita maxima	121	23.4-37.8	30.1	2.1	10.8-18.0	14.4	1.1
Cucumis sativus	122	25.2-36.0	31.2	1.9	10.8-18.0	14.8	1.2
Perennial Phlox	93	25.2-36.0	31.7	1.9	10.8-18.0	14.7	1.1
	123	25.2-37.8	32.0	1.9	10.8-18.0	14.4	1.2
	87	25.2-36.0	31.8	1.8	10.8-18.0	14.4	1.2
	86	25.2-37.8	31.8	1.8	10.8-19.8	14.5	1.5

7. 100 conidia from each collection were measured.
8. The numbers used in this column refer to the numbers in the Appendix, where information concerning the identity of the specimens will be found.

It is seen that the actual measurements of both length and width of conidia do not vary greatly from one mildew to the next. The greatest differences in conidial length are 30.12 microns for the mildew on Cucurbita maxima to 39.02 microns for the mildew on Cerinthe major (specimen 116). Conidial width is somewhat more uniform, varying from 13.55 microns for Zinnia elegans conidia (specimen 114) to 18.0 microns for the mildew on Inula helenium.

The data for the ratio of width to length show that the conidia from the different sources have the same general shape. All conidia are essentially twice as long as they are wide. By the commonly accepted descriptive terms they are cylindric, ellipsoidal or doliform in shape.

DISCUSSION

The three special forms of Erysiphe cichoracearum sensu Salmon demonstrated by this study, the zinnia mildew, the phlox mildew and the cucurbit mildew, are distinct one from the other. The zinnia mildew is limited to nineteen species in thirteen genera of the Compositae and to Cerinthe major of the Boraginaceae and Salpiglossis sinuata of the Solanaceae, as is shown in Table IV. The phlox mildew has been found to be closedly restricted to Phlox drummondii and the cultivated perennial phlox, which is either P. maculata or P. paniculata or various hybrids of these two species. The cucurbit mildew used in this study has been found to be closely restricted to the Cucurbitaceae.

Comparisons of the host specialization for the mildews of the present study with previously recognized special forms or biologic species present difficulties. While it is desirable that the same species of hosts be used in all studies of host specialization it is difficult to obtain seeds of all species of hosts used by all investigators. Consequently, the mildews have been tested on the species available. The three mildews of the present study have been tested on as many as possible of the species listed by Salmon (1900) as hosts for Erysiphe cichoracearum. Comparisons of the characteristics of the zinnia, phlox and cucurbit mildews of the present study with those of two special forms of E. cichoracearum sensu Blumer and of several of the species segregated from E. cichoracearum by Blumer follows. The comparisons are made to determine to which of these taxa designated by Blumer the present three special forms of E.

cichoracearum might belong.

Erysiphe cichoracearum as treated by Blumer is reported on a number of species susceptible to the zinnia mildew. Scorzonera hispanica is cited as the only susceptible species for Blumer's E. cichoracearum f.sp. scorzonerae. This special form was established as a result of Bouwens' experiments (1927). In Miss Bouwens' experiments no other species of the hosts used in the present study was inoculated. It is possible in view of the results on Scorzonera hispanica, that the zinnia mildew may be the same as the form she studied. However, studies to test the European mildew on S. hispanica on other species susceptible to the zinnia mildew are necessary before this can be definitely determined.

Blumer established Erysiphe cichoracearum f.sp. euhieracii as a result of experiments using a mildew from Hieracium murorum. It infected twelve other species in the subgenus Euhieracium, one of which was H. prenanthoides. H. prenanthoides was found to be susceptible to the zinnia mildew. However, in the present study H. murorum and H. silvaticum, which are hosts for f.sp. euhieracii of Blumer, were not infected by the zinnia mildew, whereas H. prenanthoides was infected in all cases. Hieracium prenenthoides therefore is a favorable host for two different special forms. No other special form of E. cichoracearum sensu Blumer has hosts in common with the zinnia mildew.

The zinnia mildew has conidia which are hyaline, ellipsoidal to doliform, with a range of 21.3-45.0 X 10.8-23.4 microns, averaging 34.2 X 15.8 microns. The perithecia are spherical, ranging from 78.7 to 157.3 microns in diameter, with an average diameter of 111.7 (106.0 to 118.5) microns. The perithecial appendages are numerous

and hyaline or brown, and are interwoven with the superficial mycelium, making it difficult to remove the perithecia from the substrate without breaking the appendages. There are from 8-20 asci per perithecium, the asci being 2-spored, occasionally 3-spored and rarely 4-spored.

Erysiphe cichoracearum as treated by Blumer has perithecia which are cited as 90-135 microns in diameter and with 10-25 asci per perithecium. The asci are described as 2- or rarely 3-spored, and the conidia are stated to be 25-45 X 16-26 microns. The conidia of the zinnia mildew agree in length with E. cichoracearum sensu Blumer, but are somewhat narrower. The range in perithecial diameter of the zinnia mildew is greater than that of E. cichoracearum as treated by Blumer. In the number of asci per perithecium there is agreement, the zinnia mildew having 8-20, while E. cichoracearum of Blumer has 10-25. Blumer gives two- and three-spored asci, while the zinnia mildew also has some four-spored asci. Blumer lists thirty-eight genera of the Compositae plus three species of the Violaceae and one each from the Polemoniaceae (Polemonium van-bruntiae) and the Solanaceae (Nicotiana tabacum). Only a few of the species listed by Blumer have been used in studies of host specialization. He includes Carlina acaulis, Hieracium prenanthoides, Inula helenium, Scorzonera hispanica, Xanthium strumarium and X. spinosum, which are susceptible to the zinnia mildew. The zinnia mildew did not infect Polemonium van-bruntiae, Nicotiana tabacum and Viola sp., but it did infect the borage, Cerinthe major, and the solanaceous species, Salpiglossis sinuata. From the characteristics of the zinnia mildew and Blumer's treatment of E. cichoracearum noted above it is seen that only minor differences exist. With slight modifications of the description of E. cichoracearum sensu Blumer the zinnia mildew can

be included with this species.

Erysiphe depressa (Wallr.) Schlecht., as recognized by Blumer, has as hosts species of Arctium in common with the zinnia mildew. Blumer states that E. depressa from Arctium minus infected A. lapna, A. palladium, A. nemorosum and A. tomentosum. Both A. minus and A. nemorosum are hosts for the zinnia mildew. Blumer did not inoculate the other species which are susceptible to the zinnia mildew. Miss Bouwens was not able to infect Scorzonera hispanica with a mildew from A. minus. Since both S. hispanica and A. minus were susceptible to the zinnia mildew at least two special forms have A. minus as a host.

Blumer (1933) states that the conidia of E. depressa are large, doliform and 35-42 X 22-26 microns. For the most part the conidia of the zinnia mildew are smaller than this, especially in width, with a range of 21.6- 45.0 X 10.8-23.4 microns. Perithecia of E. depressa range from 112-133 microns, averaging 123 microns in diameter. The zinnia mildew has a larger range and a smaller average diameter of the perithecia. In this connection the data from Zinnia elegans (specimen 3 in Table VII) should be given special consideration, since this collection was made from plants used as the source of conidia for some of the infection experiments performed during 1951-1952. This collection has a range in perithecial diameters of 99.45-137.7 microns, with an average for two hundred perithecia of 118.5 microns. These data more nearly correspond to E. depressa than do the other collections of the zinnia mildew. E. depressa is described as having 8-14 asci which are exclusively 2-spored, whereas the zinnia mildew has 8-20 asci which are primarily 2-spored, but with some 3- and 4- spored asci. The differences that exist

between these two mildews are minor ones, and since there is overlapping in the values for the conidial measurements and the perithecial diameters of E. depressa and the zinnia mildew, the zinnia mildew might be included in E. depressa.

Another species recognized by Blumer on the Compositae is Erysiphe montagnei. This is restricted to species of Cirsium according to Blumer. He describes E. montagnei as having mostly two but rarely three or four spores per ascus. In this respect there is agreement with the zinnia mildew although the latter has longer conidia than those of E. montagnei (32-36 X 15-19 microns). The diameters of the perithecia of these two mildews differ. The zinnia mildew has a range of 78.7-157.3 microns, with an average of 111.7 microns, while E. montagnei has a range of 90-108 microns, averaging 99 microns. Blumer describes E. montagnei as having exclusively brown perithecial appendages and less than twelve asci per perithecium. In these two characteristics the zinnia mildew differs slightly from E. montagnei. E. montagnei occurs on nine species of Cirsium, one of which is C. arvense. This species was not infected by the zinnia mildew, although only two plants were inoculated so the results are not conclusive. Because of the prevalence of overlapping ranges in size of conidia and perithecia, and because E. montagnei has not been tested on species outside the genus Cirsium, the zinnia mildew might belong to this species of Blumer, E. montagnei.

Erysiphe artemisiae (Wallr.) Grev., as recognized by Blumer (1933), is restricted to species of Artemisia of the Compositae. Blumer characterizes E. artemisiae as having conidia 26-32 X 17-22 microns. The perithecia are 97-123 microns, averaging 110 microns in diameter, and

they have hyaline or weakly browned appendages. There are 7-20 asci which are 2-spored. The zinnia mildew was tested on Artemisia absinthium and A. vulgaris, both of which are given as hosts for E. artemisiae by Blumer; they were not infected by the zinnia mildew. The zinnia mildew has a greater average perithecial diameter than E. artemisiae. Likewise the conidia of the zinnia mildew are larger. For both the conidial and perithecial characteristics, however, E. artemisiae is within the limits of the zinnia mildew. In the number of asci per perithecium there is agreement between these two mildews, E. artemisiae having 7-20 while the zinnia mildew has 8-20. With the exception of the number of ascospores in the asci of E. artemisiae (2) as compared with the zinnia mildew (mostly 2) the two mildews are essentially the same morphologically.

Erysiphe fischeri Blumer on species of Senecio of the Compositae is characterized by Blumer (1933) as having conidia 28-35 X 14-19 microns. Its perithecia are 111-150 microns in diameter, averaging 128 microns. They have brown appendages according to Blumer. He describes E. fischeri as having 15-20 asci that are 2-spored. The conidia of the zinnia mildew have a greater range in size than those of E. fischeri, but there is overlapping of ranges. The perithecia of E. fischeri are larger, but there is overlapping in the range of perithecial diameter with the zinnia mildew. The zinnia mildew has mostly 2-spored asci, whereas E. fischeri is given as having exclusively 2-spored asci. The differences between these two mildews are not great.

Erysiphe horridula (Wallr.) Lev. on the Boraginaceae was recognized by Blumer, partly on the results of his infection experiments

(1922a) and partly because of the often 3-spored asci on some boraginaceous hosts. Blumer (ibid.) cites Cerinthe major as the common host for all special forms of the borage mildew which he investigated. In his experiments (1922a) he did not inoculate species of hosts outside the Boraginaceae. In the present experiments C. major was always infected by the zinnia mildew, while Symphytum officinale, Anchusa italica, Cynoglossum officinale and Cerinthe minor, hosts for E. horridula, were not infected.

As described by Blumer, E. horridula has ellipsoidal to doliform conidia, 29-40 X 16-22 microns. The diameters of the perithecia are 95-135 microns, with an average diameter of 115 microns. There are 10-20 asci which are 2-spored, rarely 3- or 4-spored. In regard to morphological characteristics for E. horridula the zinnia mildew agrees quite well.

Erysiphe polyphaga is reported on several species which are susceptible to the zinnia mildew. The original, tentative description of this species by Hammarlund (1945) is rather meager, but it has been supplemented by Blumer (1950, 1952) by the addition of measurements of conidia and perithecia from the mildew on certain hosts. The conidia of E. polyphaga as given by Blumer are ellipsoidal, doliform or cylindrical, 27.74-32.7 X 14.57-18.2 microns. The conidia of the zinnia mildew are somewhat longer than this, but have essentially the same width. Blumer (1952) states that the perithecia of E. polyphaga are 88-135, averaging 105 microns. Von Röder (1937) obtained an average of 110.0 microns for a mildew on Cucumis sativus that he identified as E. cichoracearum, but which Blumer regards as E. polyphaga. The zinnia mildew has a greater range in perithecial

diameter and a slightly greater average diameter. In the number of asci E. polyphaga and the zinnia mildew both have 8-20. They also both have 2-, 3- or 4- spored asci. Blumer (ibid.) states that the primary consideration for the recognition of E. polyphaga is its wide host range rather than distinctive morphological characteristics. From the cultural studies of Hammarlund (1945) and Blumer (1950, 1952) E. polyphaga occurs on eighty-five species in thirty-six genera of fifteen families of flowering plants. This is a considerably greater range in species of hosts than that of the zinnia mildew, which infected nineteen species in thirteen genera of composites and one species each of the Boraginaceae and Solanaceae. E. polyphaga and the zinnia mildew have been found to infect Helianthus annuus and Scorzonera hispanica of the Compositae. The following hosts for E. polyphaga were not infected by the zinnia mildew: Viola sp. (V. tricolor maxima hort.), Nicotiana tabacum, Dahlia sp. (D. variabilis) and Antirrhinum majus. The zinnia mildew has been tested on species from eleven families of plants and if it is E. polyphaga a wider range of hosts would be expected. Instead the zinnia mildew has a host range limited primarily to the Compositae, but also including species from rather distantly related families. With the exception of the differences in host range E. polyphaga and the zinnia mildew agree quite well.

No special forms or biologic species have been previously established, as a result of infection experiments, on the species of Xanthium, Mikania, Inula, Carlina, Lactuca, Cosmos, Felicia or Salpiglossis, which have been found to be susceptible to the zinnia mildew.

The results of this study show that the phlox mildew is closely restricted to Phlox drummondii and to the cultivated perennial phlox. Other species of the Polemoniaceae, as well as species of other fam-

ilies, gave negative results. For E. cichoracearum Salmon (1900) lists only Phlox divaricata, P. drummondii and P. paniculata for the Polemoniaceae. Species of the Polemoniaceae have not been used in other studies of the host specialization of the powery mildews.

The conidia of the phlox mildew are ellipsoidal to doliform, 25.2-37.8 X 10.8-19.8 microns, averaging 31.8 X 14.5 microns. The perithecia are sperical, 78.7-162.2 microns, averaging 110.3 (101.1-116.9) microns in diameter. The perithecial appendages are hyaline or brown, numerous and interwoven with the adjacent mycelium. There are 8-22 asci which are mostly 2-spored, occasionally 3- and rarely 4-spored.

The conidia of the phlox mildew are somewhat less variable than the conidia of the zinnia mildew. However, the range in size of the conidia for the phlox mildew is within that of the zinnia mildew. The perithecia of the phlox mildew and the zinnia mildew are nearly the same, the phlox mildew having a higher upper limit of the range and a somewhat smaller average diameter. The numbers of asci are essentially the same, 8-20 for the zinnia mildew as compared with 8-22 for the phlox mildew. Both have mostly 2-spored asci, although there are occasionally more. These two mildews are therefore morphologically similar.

Blumer (1933) cites Polemonium van-bruntiae (P. caeruleum) as a host for E. cichoracearum. This species of host was included by Blumer because of morphological characteristics of specimens of the mildew, not as a result of infection experiments. No other species of the Polemoniaceae are given as hosts by Blumer. Polemonium van-bruntiae was inoculated in the present study with conidia of the phlox mildew without infection occurring.

The phlox mildew has conidia which are smaller in both length and width than conidia of E. cichoracearum sensu Blumer (25-45 X 16-23 mic-

rons). The range in perithecial diameter of the phlox mildew exceeds that of E. cichoracearum of Blumer, 78.7-162.2 microns as compared with 90-135 microns. The numbers of asci are similar, 10-25 for E. cichoracearum of Blumer and 8-22 for the phlox mildew. Blumer's E. cichoracearum is described as having only 2- or 3-spored asci while the phlox mildew rarely has 4-spored as well as 2- and 3-spored asci. However, the 4-spored asci are few, 0.5 to 1.5%. Although the phlox mildew differs more than the zinnia mildew from E. cichoracearum sensu Blumer the differences are not great.

The number of ascospores for the phlox mildew agrees with those for E. horridula and E. montagnei, both of which have 2,3 or 4 ascospores per ascus. The conidia of the phlox mildew are 25.2-37.8 X 10.8-19.8 microns, as compared to 29-40 X 16-22 microns for E. horridula. The perithecial diameters for the phlox mildew have a range greater than the range of 95-135 microns for E. horridula. In ascus number the phlox mildew essentially agrees with E. horridula which has 10-20. Except for the host species the phlox mildew agrees rather well with E. horridula

Erysiphe montagnei has conidia 32-36 X 15-19 microns according to Blumer. The limits for the length of conidia of E. montagnei are thus contained within the limits for the conidia of the phlox mildew. In conidial width there is an overlapping of the ranges. The perithecial diameters for the phlox mildew are greater than the ranges for E. montagnei, although the range of 90-108 microns for this species is within the range for the phlox mildew, 78.7-162.2 microns. Blumer gives the ascus number as less than twelve for E. montagnei, whereas the phlox mildew has 8-22 asci. Blumer considered E. montagnei to be restricted to species of Cirsium, although this restriction was based on the results of inoculating only species of Cirsium.

Except for hosts the phlox mildew is similar to Erysiphe polyphaga. No infection experiments have been carried out with E. polyphaga on species of Phlox. The phlox mildew failed to infect Helianthus annuus, Dahlia sp. and Viola sp. (probably V. tricolor maxima hort.), which are hosts for E. polyphaga. The phlox mildew and E. polyphaga have have essentially the same sized conidia. The range in size of perithecia of the phlox mildew is somewhat greater than for E. polyphaga. The average diameters are 110.3 microns for the phlox mildew and 105 or 110 microns for E. polyphaga. In characteristics of the asci and ascospores these two mildews agree quite well, both having 2-4 ascospores in the asci and 8-22 asci for the phlox mildew and 8-20 for E. polyphaga.

For the cucurbit mildew the results of this study and of the study by Miller and Barrett (1931) indicate a specialization to the Cucurbitaceae. The writer found that Cucurbita pepo, C. maxima, Echinocystis lobata and Sicyos angulatus were susceptible, whereas Momordica charanthia and Bryonia dioica, as well as species from other families, were not infected. Reed (1907,1908) infected Momordica charanthia with a mildew from Cucurbita maxima. He also reported infection of Helianthus annuus and Plantago rugelii by a mildew on C. maxima. Reed states that the mildews that developed on H. annuus and P. rugelii were successfully transferred back to squash plants. Although infections occurring on control plants throw some doubt on these results, the successful reciprocal infections seem to authenticate Reed's results on H. annuus and P. rugelii. Miller (1938) could not infect sunflower with the cantaloupe mildew, nor was the reciprocal successful. The writer was unable to infect

either H. annuus or P. rugelii with the cucurbit mildew used in this study. It therefore appears to be distinct from that studied by Reed.

The conidia of the cucurbit mildew of this study are hyaline, ellipsoidal to doliform and 23.4–37.8 X 10.8–18.0 microns, averaging 30.7 X 14.6 microns. The range in conidial length of this mildew corresponds quite well with the range for the zinnia mildew and the phlox mildew. The range in width of conidia for the cucurbit mildew is the smallest of the three mildews of this study. All three mildews have 10.8 microns as the lower limit of the range, but the cucurbit mildew varies to 18.0 microns, while the phlox mildew extends to 19.8 microns and the zinnia mildew up to 23.4 microns. The average conidial size for the cucurbit mildew is 30.7 X 14.6 microns, as compared with 31.8 X 14.5 microns for the phlox mildew and 34.2 X 16.6 microns for the zinnia mildew. Although differences in the conidia of these three mildews exist the similarities are also apparent from the overlapping ranges for both length and width. These mildews of this study differ also in their ability to form perithecia. The phlox mildew with its close restriction produces abundant perithecia regularly. The zinnia mildew only occasionally forms perithecia on Zinnia elegans. The cucurbit mildew, with its different degrees of specialization, very rarely forms perithecia.

Hammarlund (1945) and Blumer (1950,1952) have found that a mildew on cucurbits infects a wide range of hosts. They conclude that this mildew is a species, E. polyphaga, which differs from E. cichoracearum both in its host specialization and in having some 3-spored and 4-spored asci. Since the cucurbit mildew used in this study did not form perithecia a comparison of the asci is not possible and compar-

isons are limited to the conidia. The size of the conidia of the cucurbit mildew of the present study agrees quite well with the size of the conidia of E. polyphaga. The latter, according to Blumer, has conidia 27.74-32.7 X 14.4-18.2 microns. The cucurbit mildew of the present study has a slightly greater range in the size of conidia.

Of the species of hosts for E. polyphaga the writer's cucurbit mildew was tested on Helianthus annuus and Viola sp. without either becoming infected. The cucurbit mildew of the present investigation was found to be restricted to the Cucurbitaceae. This is a much narrower range of hosts than that of E. polyphaga. In the present study the cucurbit mildew was tested on a sufficiently wide range of host families and it would seem that any tendency toward a wide host range would have become apparent in the results of the experiments.

The conidia of Erysiphe fischeri essentially agree with those of the cucurbit mildew studied by the writer. As given by Blumer, E. fischeri has conidia 28-35 X 14-19 microns. There is a greater range in size shown by the cucurbit mildew studied by the writer, although there is overlapping of the ranges.

The conidia of Erysiphe salviae are given by Blumer as being 28-35 X 14-18 microns. The ranges in size for the conidia of this species and the cucurbit mildew of this study coincide in part, so that distinctions would be difficult to draw.

Erysiphe valerianae, as described by Blumer, has conidia 30-35 X 15-19 microns. These values for conidial size also essentially agree with those for the cucurbit mildew of the present study, with the exception that the latter has a wider range in size. This range, however, includes the range in size for the conidia of E. valerianae.

as given by Blumer.

The conidial size range for Erysiphe artemisiae, as given by Blumer, has a somewhat narrower range than the present cucurbit mildew, 26-32 X 17-22 microns for E. artemisiae as compared with 23.4-37.8 X 10.8-18.0 microns for the cucurbit mildew.

It is evident from the above discussions that the three mildews of this study, the zinnia mildew, the phlox mildew and the cucurbit mildew, do not differ greatly in their morphology from each other or from Erysiphe horridula, E. montagnei, E. depressa, E. artemisiae, E. valerianae, E. salviae, E. fischeri, E. cichoracearum sensu Blumer and E. polyphaga. As shown in Table III, the characteristics for the different species of mildews recognized by Blumer as segregated from E. cichoracearum sensu Salmon, there is a great amount of overlapping in the several characteristics for these mildews.

Restrictions to families or genera of hosts have been based on a rather narrow range of species of hosts in a number of instances. As has already been emphasized in many investigations the hosts studied were limited to one family or in some instances to one genus. This decidedly limits the ranges of hosts that can be demonstrated. Such is the situation in studies concerning Erysiphe fischeri, E. salviae, E. lamprocarpa, E. valerianae, E. artemisiae, E. depressa, E. montagnei and E. horridula. If a wider range of hosts had been employed there is the possibility that such species or forms might have been found to have a much wider range of hosts than that cited by Blumer.

E. polyphaga is outstanding for its wide host range. Hammarlund and Blumer, with a mildew derived from Cucumis sativus of the Cucurbitaceae, have shown that E. polyphaga infects eighty-five species

of hosts from fifteen families. The cucurbit mildew used by Reed was shown to infect primarily certain members of the Cucurbitaceae and Helianthus annuus of the Compositae and Plantago rugelii of the Plantaginaceae. Reed inoculated only three species of Aster and Solidago caesia, in addition to H. annuus and P. rugelii, from families other than the Cucurbitaceae. His mildew might have had a wider range of hosts if more species had been inoculated. On the other hand the cucurbit mildew of the present study was inoculated onto thirteen species of the Compositae, three species of the Labiatae, two species each from the Boraginaceae, Plantaginaceae and Polemoniaceae and one species of the Violaceae, in addition to members of the Cucurbitaceae. With this extensive series of host families any tendency for the mildew to infect species outside the Cucurbitaceae would probably be expected to be manifested. It therefore appears that several forms with different degrees of specialization occur on cucurbits, E. polyphaga with its extremely wide host range, Reed's mildew which infected also two species outside the Cucurbitaceae and the mildew studied by the writer which was restricted to the Cucurbitaceae.

If the present cucurbit mildew is included in E. polyphaga one of the primary differences, wide host range, used in separating the species would not apply to the species as a whole. From its host specialization it cannot be placed elsewhere with any certainty.

The host range of the zinnia mildew is greater than any of the mildews under discussion except E. polyphaga. If it is included in that species it would introduce a special form intermediate in both morphology and host range between the mildew recognized by Hammar-

lund and Blumer as E. polyphaga and several other species. If included in the other species with which it has hosts in common it will reduce the differences in host specialization now recognized for them.

As far as morphology is concerned the phlox mildew could equally well be placed in several of the segregates from E. cichoracearum sensu Salmon. If host specialization is emphasized its very limited specialization to three species of Phlox sharply separates it from other mildews and might be considered as justification for its recognition as a distinct species. It seems evident however that the powdery mildews include many forms with various degrees of host specialization and intergradation in morphology. It is doubtful whether they should be separated into distinct species. As far as the mildews of this study are concerned it seems best to consider them as belonging to one species, Erysiphe cichoracearum sensu Salmon, distinguished from each other by their host specialization. Whether any or all of the species segregated by Blumer should be recognized as separate species is doubtful. It is probable that when studies are made with hosts from more families some of the differences now emphasized will be less.

The few plants of the otherwise susceptible species, Xanthium chinense, Mikania scandens, Lactuca perennis, Salpiglossis sinuata and Phlox drummondii, which remained mildew-free indicate possibilities for the development of resistant strains of hosts. As noted above this has been demonstrated for the phlox mildew by Mains (1942). Varieties of cantaloupe with a high resistance to the powdery mildew of cucurbits have been bred by various workers.

The data from the field experiment with the commercial zinnias

indicate the possibilities for the development of resistant zinnias. However, there was no pronounced resistance exhibited by these zinnias under the artificially induced epiphytotic conditions of the field experiment. Therefore, it did not seem feasible for purposes of this study to continue this line of investigation.

SUMMARY

1. A powdery mildew from Zinnia elegans is shown to infect Z. elegans, Z. pauciflora, Z. verticillata, Helianthus annuus, Arctium minus, A. nemorosum, Xanthium chinense, X. spinosum, X. strumarium, Mikania scandens, Hieracium alpinum, H. prenanthoides, Inula helenium, Carlina acaulis, Lactuca perennis, Cosmos sp., Scorzonera hispanica and Felicia amelloides of the Compositae, Salpiglossis sinuata of the Solanaceae and Cerinthe major of the Boraginaceae.

2. A phlox mildew is shown to be restricted to Phlox drummondii and the cultivated perennial phlox, no infection occurring on thirty-four other species of hosts which have been reported for Erysiphe cichoracearum.

3. A cucurbit mildew from the vicinity of Ann Arbor is shown to be restricted to the Cucurbitaceae. Reed's infection of Helianthus annuus and Plantago rugelii by a cucurbit mildew was not duplicated.

4. A comparison of the perithecia of the phlox and zinnia mildews and of the conidia of the phlox, zinnia and cucurbit mildews failed to provide differences to justify specific separation.

5. The zinnia, phlox and cucurbit mildews are best recognized as special forms of Erysiphe cichoracearum sensu Salmon, distinguished by marked differences in their host specialization, but not by morphological differences.

6. In field studies to determine if resistance to powdery mildew could be obtained in zinnia, twenty-nine accessions of commercial zinnias are subjected to an epiphytotic of the zinnia mildew. Under these rigorous conditions no plants were completely free from the mildew. Six plants were infected later than the others, this lateness of in-

fection under epiphytotic conditions being taken as a form of resistance. It seems probable that with less abundant inoculum these plants probably would have shown much less infection.

Appendix: Identification of collections of *Erysiphe cichoracearum* sensu Salmon

Specimen*:	Collector or Exsiccati Number:	Locality:
1	J. Schmitt 7 a	Ann Arbor, Michigan
2	E.B. Mains (Nov. 25, 1934)	Ann Arbor, Michigan
3	J. Schmitt 152	Ann Arbor, Michigan
4	Bartholomew, Fungi Columb. 2929	Evanston, Illinois
5	T.W. Johnson	Waukegan, Illinois
6	Seym. and Earle, Econ. Fungi 293 b	New Brunswick, New Jersey
7	V.M. Spaulding 170	Ann Arbor, Michigan
8	G.H. Hicks	Ann Arbor, Michigan
9	Seym. and Earle, Econ. Fungi 293 a	Byron, Illinois
10	H.C. Greene 132	Baglevills, Wisconsin
11	Bartholomew, Fungi Columb. 2624	Fremont, Nebraska
12	Bartholomew, Fungi Columb. 1926	Stockton, Kansas
13	G.H. Hicks	Corruna, Michigan
14	Ell. and Ev., N. Am. Fungi 3215 b	Fort Collins, Colorado
15	L.N. Johnson 1823	Ann Arbor, Michigan
16	E.T. and S.A. Harper	Smithfield, W. Virginia
17	V.M. Spaulding 169	Ann Arbor, Michigan
18	(No collector listed)	Ann Arbor, Michigan
19	L.W. Buttall 1223	Fayette Co., W. Virginia
20	Seym. and Earle, Econ. Fungi 321	Weston Mills, New Jersey
21	Krieger, Fungi Saxon.	Konigstein, Germany
22	K. Starcs Herbarium 595	Prov. Vidzeme, Latvia
23	Sydow, Mycoth. germ. 2675	Brandenburg, Germany
24	Sydow, Mycoth. germ. 2676	Brandenburg, Germany
25	Briosi and Cavara 381	Meaux, France
26	(No collector listed)	Leipzig Botan. Gardens
27	K. Starcs Herbarium 528	Prov. Vidzeme, Latvia
28	Bartholomew, Fungi Columb. 5016	Red Cloud, Nebraska

*: The numbers used in this column refer to the collections as numbered in Tables VII and VIII.

Appendix: Continued:

Specimen:	Collector or Exsiccati Number:	Locality:
29	Briosi and Cavara 263	Meaux, France
30	Rehm: Ascomyceten 1500	München, Germany
31	Mycofl. Saximon. Exsic., Solheim 597	Powell, Wyoming
32	L.N. Johnson 1871	Ann Arbor, Michigan
33	E.B. Mains	Coldwater, Michigan
34	Bartholomew, Fungi Columb. 4225	Denver, Colorado
35	H.C. Greene 288	Big Bend, Wisconsin
36	Mycofl. Saximon. Exsic., Solheim 802	Big Horn, Sheridan Co., Wyo.
37	Mycofl. Saximon. Exsic., Goodding 569	7 Mi. Lake, Albany Co., Wyo.
38	Krieger, Fungi Saxon.	Waltersdorf, Germany
39	Herbarium Parksianum 4470	Humboldt Co., California
40	K. Staros Herbarium 220	Prov. Vidzeme, Latvia
41	Bartholomew, Fungi Columb. 2225	Golden, Colorado
42	Bartholomew, Fungi Columb. 2725	Littleton, Colorado
43	J. Schmitt 150	Provo, Utah
44	E.B. Mains	Ann Arbor, Michigan
45	L.W. Nuttall 1707	Fayette Co., W. Virginia
46	K. Staros, Fl. Bavarica 2259	Hersbruck, Bavaria
47	E.B. Mains	Coldwater, Michigan
48	Ell. and Ev., N. Am. Fungi 3215 a	Fort Collins, Colorado
49	C.H. Kauffman	New Richmond, Michigan
50	Bartholomew, Fungi Columb. 1821	Natoma, Kansas
51	A.J. Pieters 54	Ann Arbor, Michigan
52	Bartholomew, Fungi Columb. 3909	Mazomanie, Wisconsin
53	J. Schmitt 153	Ann Arbor, Michigan
54	B. Fink, Ascomycetes of Ohio, 512	Mason, Ohio
55	Mycofl. Saximon. Exsic., Aven Nelson 10681	Laramie, Wyoming
56	H.C. Greene 765	Madison, Wisconsin
57	Colorado Fungi, W.A. Archer	Larkspur, Colorado
58	Bartholomew, Fungi Columb. 2322	Golden, Colorado
59	Ell. and Ev., N. Am. Fungi 2916	Berkeley, California

Appendix: Continued:

Specimen:	Collector or Exsiccati Number:	Locality:
60	Sydow, Mycoth. germ. 2674	Stralsund, Pommern, Germany
61	Sydow, Mycoth. germ. 2673	Tamsel, Brandenburg, Germany
62	Flora of New York, Rubinger	Ithaca, New York
63	Sydow, Mycoth. germ. 317	Harz, Germany
64	Shear, Fungi Columb. 1435	Walla Walla, Washington
65	Bartholomew, Fungi Columb. 2121	Stockton, Kansas
66	Krieger, Fungi Saxon. 826	Tillnik, Germany
67	A. Povah Fp 701	Isle Royale, Michigan
68	Fungi Dak. 162	Kulm, N. Dakota
69	Krieger, Fungi Saxon. 1815	Pirna
70	Mycofl. Saximon. Exsic., Aven Nelson 10772	Laramie, Wyoming
71	Bartholomew, Fungi Columb. 2226	Salt Lake Co., Utah
72	Sydow, Mycoth. germ. 2918	Tamsel, Brandenburg, Germany
73	Bartholomew, Fungi Columb. 3521	Cassels, Colorado
74	Fungi Californica 633	Humboldt Co., California
75	Fungi Californica 632	Humboldt Co., California
76	Mycofl. Saximon. Exsic. 109, Rollins 1079	Laramie, Wyoming
77	Krieger, Fungi Saxon. 1918	Konigstein
78	Sydow, Mycoth. germ. 3096	Bayer, Regensburg, Germ.
79	Krieger, Fungi Saxon. 1666	Konigstein
80	Sydow, Mycoth. germ. 3095	Tamsel, Brandenburg, Ger.
81	Mus. Botan. Stockholm	Bot. Gard., Uppsala, Sweden
82	Bartholomew, Fungi Columb. 2430	Boulder, Colorado
83	Bartholomew, Fungi Columb. 2429	Tolland, Colorado
84	Fungi Californica, Tracy 9025	Humboldt Co., California
85	Bartholomew, Fungi Columb. 3522	Chicago, Illinois
86	Bartholomew, Fungi Columb. 2623	Lone Pine, Nebraska
87	Bartholomew, Fungi Columb. 2120	St. Paul, Nebraska
88	Bartholomew, Fungi Columb. 3709	Rock River, Wyoming
89	J. Schmitt 149	Provo, Utah
90	H.S. Jackson 4816	Toronto, Ontario, Canada
91	J.A. Parmelee 23711	Ottawa, Ontario, Canada

Appendix: Continued:

Specimen:	Collector or Exsiccati Number:	Locality:
92	H. Mukai	Ann Arbor, Michigan
93	J. Schmitt 11	Ann Arbor, Michigan
94	H.C. Greene 783	Madison, Wisconsin
95	V.M. Spaulding 185	Ann Arbor, Michigan
96	Seym. and Earle, Econ. Fungi 46	Plymouth, New Hampshire
97	(No collector listed)	
98	G.H. Hicks	
99	Flora of New York, Rubinger	
100	Ell. and Ev., N. Am. Fungi 3006	
101	Ellis, N. Am. Fungi 424 b	
102	Fungi Californica 631	
103	Fungi Californica 630	
104	H.C. Greene 14	
105	Seymour, U.S.D.A. Mycol. Coll.	
106	Bartholomew, Fungi Columb. 1822	
107	W.J. Beal	
108	Ellis, N. Am. Fungi 424 a	
109	Bartholomew, Fungi Columb. 2024	
110	Bartholomew, Fungi Columb. 3425	
111	Krieger, Fungi Saxon. 2206	
112	E.B. Mains (Sept. 1946)	
113*	J. Schmitt 7 b	
114*	J. Schmitt 7 c	
115	Fresh material of the zinnia mildew on Zinnia elegans.	
116	Fresh material of the zinnia mildew on Cerinthe major (Field accession).	
117	Fresh material of the zinnia mildew on C. major (After infection from Z. elegans)	
118	Fresh material of the zinnia mildew on Inula helenium.	
119	Fresh material of the zinnia mildew on Helianthus annuus.	
120	E.B. Mains	Ann Arbor, Michigan
121	Philippine Fungi, Stevens 966	Laguna, P.I.
122*	Seym. and Earle, Econ. Fungi 438	Amherst, Mass.
123	E.B. Mains 4998	Ann Arbor, Michigan

*: These mildews developed in greenhouses.

Appendix: Continued:

Specimen:	Collector or Exsiccati Number:	Locality:
92	H. Mukai	Ann Arbor, Michigan
93	J. Schmitt 11	Ann Arbor, Michigan
94	H.C. Greene 783	Madison, Wisconsin
95	V.M. Spaulding 185	Ann Arbor, Michigan
96	Seym. and Earle, Econ. Fungi 46	Plymouth, New Hampshire
97	(No collector listed)	Ann Arbor, Michigan
98	G.H. Hicks	Ann Arbor, Michigan
99	Flora of New York, Rubinger	Ithaca, New York
100	Ell. and Ev., N. Am. Fungi 3006	Newfield, New Jersey
101	Ellis, N. Am. Fungi 424 b	West Chester, Penna.
102	Fungi Californica 631	Berkeley, California
103	Fungi Californica 630	Berkeley, California
104	H.C. Greene 14	Verona, Wisconsin
105	Seymour, U.S.D.A. Mycol. Coll.	Waverley, Mass.
106	Bartholomew, Fungi Columb. 1822	Stockton, Kansas
107	W.J. Beal	North Lansing, Michigan
108	Ellis, N. Am. Fungi 424 a	Decorah, Iowa
109	Bartholomew, Fungi Columb. 2024	Stockton, Kansas
110	Bartholomew, Fungi Columb. 3425	Stockton, Kansas
111	Krieger, Fungi Saxon. 2206	Pirna
112	E.B. Mains (Sept. 1946)	Ann Arbor, Michigan
113*	J. Schmitt 7 b	Ann Arbor, Michigan
114*	J. Schmitt 7 c	Ann Arbor, Michigan
115	Fresh material of the zinnia mildew on *Zinnia elegans*.	
116	Fresh material of the zinnia mildew on *Cerinthe major* (Field accession).	
117	Fresh material of the zinnia mildew on *C. major* (After infection from *Z. elegans*)	
118	Fresh material of the zinnia mildew on *Inula helenium*.	
119	Fresh material of the zinnia mildew on *Helianthus annuus*.	
120	E.B. Mains	Ann Arbor, Michigan
121	Philippine Fungi, Stevens 966	Laguna, P.I.
122*	Seym. and Earle, Econ. Fungi 438	Amherst, Mass.
123	E.B. Mains 4998	Ann Arbor, Michigan

*: These mildews developed in greenhouses.

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