Fungus Pathogens of Prairie Plants in Iowa

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Abstract. Parasitic fungi have long been recognized as significant factors in the normal growth, survival, and yield of cultivated plants. However, little attention has been given to the parasitic fungi of native prairie plants or to their impact on their host plants in a tallgrass prairie. Basic to consideration of their impact is information concerning the presence and prevalence of specific fungi on host plant species. Since the early 1980's, we have made collections throughout the growing season of fungal parasites on the aboveground parts of plants from prairie preserves and private prairies in Iowa. Over two hundred species of fungi have been documented. This report discusses the fungi found on 25 common tallgrass prairie plants from 10 prairies in northern Iowa and one in central Iowa. It includes 43 fungi not reported in Gilman and Archer's 1929 paper on the plant parasitic fungi in Iowa or in Gilman's later supplements to that paper. An additional six fungus species were not reported previously on the hosts on which we found them but were listed on other host species. With knowledge of the fungus flora, we can evaluate its impact on the host plant's competitive ability and better interpret this component of the biological and environmental factors that shape our prairies.

Key words: Prairie plant diseases, fungus diseases, rusts, smuts, leaf spots

Introduction

Often overlooked and underappreciated, the fungi are crucial members of the prairie biological community. Major activities of the fungi include:

1. The fungi recycle such mineral nutrients as nitrogen, phosphorous, and potassium which are necessary to continued life for *every* organism. The fungi decompose cellulose and other materials in plant debris and use the carbohydrates as their energy source, assimilating some of the minerals into their living protoplasm. Individual cells of the mycelium are often short-lived, and the minerals eventually are available for use by other living organisms, including prairie plants.
2. Some fungi are very significant because they establish a mycorrhizal relationship with the roots of green plants. The mycorrhizal fungus expedites the movement of phosphorus, water, and possibly other nutrients into the plant, while it receives from the plant the materials necessary for its growth and survival.
3. Fungi are the major pathogens of plants. They may interfere with seedling survival and establishment, restrict the development and competitive ability of growing plants, prevent reproduction, or even directly kill individuals.

These three vital activities have not been studied intensively for fungi associated with prairies. General studies of decomposer fungi as they break down plant materials of all kinds do give insight into what happens in the prairie (Frankland et al, 1982). Numerous studies of mycorrhizal relationships of many nonprairie plants also give insight into what may be probably happening in the prairie (Read et al, 1992). In both situations, more specific studies of the fungi involved are needed to gain a better view of how these fungi affect and are affected by the prairie plants.

The limited information on fungal diseases of midwestern prairie plants has come primarily from state treatments of fungal diseases on plants. Trelease (1884) and Davis (1903, 1926) reported on the parasitic fungi of Wisconsin. Later, Greene added to the information on fungal plant parasites in Wisconsin in a series of 33 papers published from 1940 to 1968. Gilman and Archer (1929) listed the fungi of Iowa parasitic on cultivated and native plants. Two supplemental lists of parasitic fungi were compiled by Gilman (1932, 1949). More recently, information on distribution of a leaf spot fungus, *Elsinoe panici,* on switchgrass (Gabel and Tiffany, 1987) and of kernel smut, *Sphacelotheca occidentalis*, on big bluestem (Snetselaar and Tiffany, 1992) documented these diseases in Iowa.

Farr et al (1989) developed an extensive compilation of occurrence of fungi on plants and plant products in the United States. Monographic treatments of genera or groups of fungi such as Cummin's books on rust fungi on grasses (1971) and rust fungi on legumes and composites (1978), Fischer's treatment of the smut fungi (1953), and books dealing with fungal parasites of a specific group of plants such as cereals and grasses (Sprague, 1950) have made available general distribution information on these fungus species. However, we lack information on the distribution and occurrence of particular fungi on their hosts in given geographic areas in specific habitats.

Our present prairie heritage in Iowa consists of scattered remnant prairies of various sizes. The plant parasitic fungi may well be determining factors in the survival or the successful growth and reproduction of individual host species. A base of current information about the disease-inducing fungi on specific host species on each prairie may be useful in interpreting changes over time. A part of this ongoing project is discussed in this paper.

Materials and Methods

Beginning in the early 1980's, but continuing more intensively to the present, collections of diseased plants have been made throughout the growing season from tallgrass prairies in Iowa. State prairie preserves and Nature Conservancy prairie preserves in these counties have been our major sources of information, but county prairie preserves and private prairies have been visited as time permitted. We have tried to visit each site in early June, in late July, and in late August but have not been able to complete these visits in each collection year. Different parasitic fungi may be present in any given year, because they are influenced by temperature regimes and available moisture. Some may develop at different times during the growing season. For example, aecial stages of rust fungi usually develop during the spring and early summer, and the host leaves or entire plants colonized by the rust soon die. Thus, they are not evident at later visits and would not be included in disease information from that site.

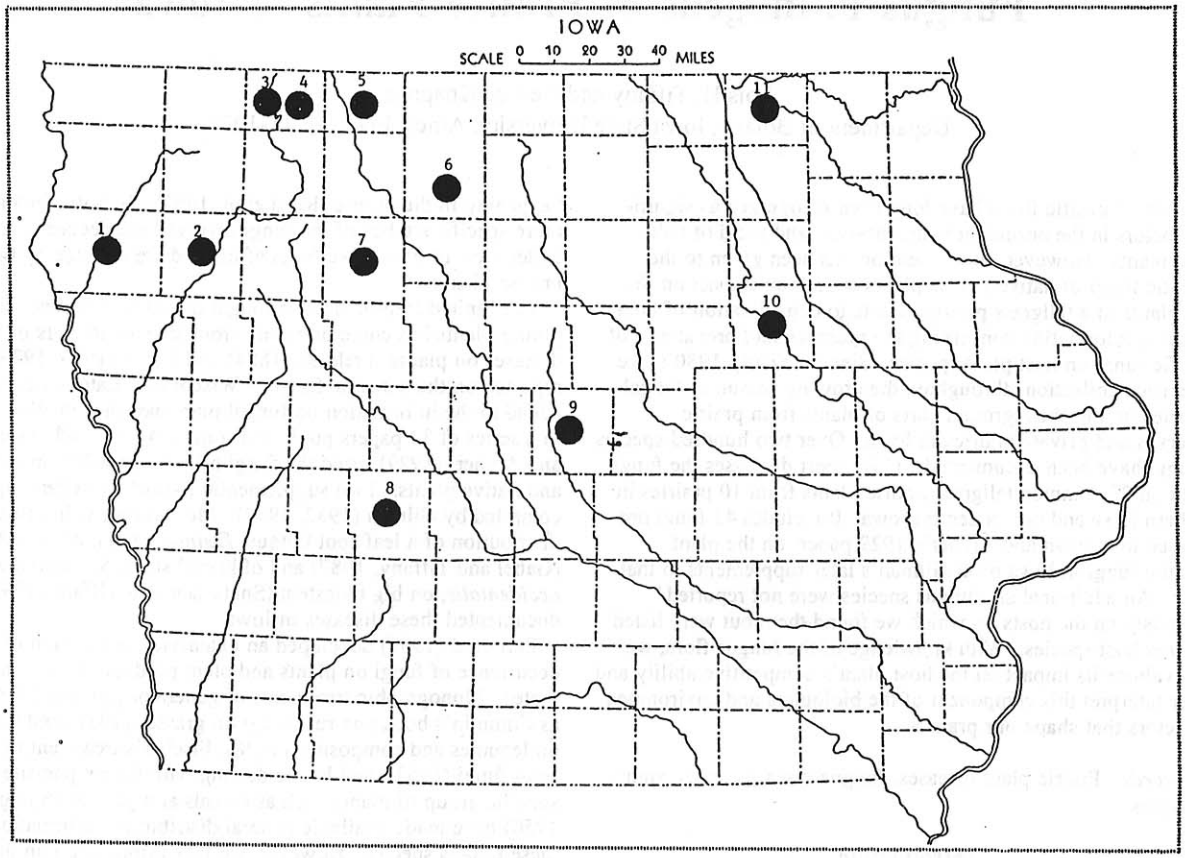

FIG. 1. Primary Iowa prairie sites included in survey of plant parasitic fungi.

Collections of diseased plant material were made in a nondestructive manner. When possible, plants were identified in the field, and only diseased parts collected, pressed, and processed. Identified fungus material in good fruiting condition on known hosts has been deposited in the mycology section of the Ada Hayden Herbarium of the Botany Department, Iowa State University (ISC) for permanent reference.

This report discusses the disease-inducing fungi found on 25 species of host plants in four groups collected on 10 native tallgrass prairies in northern Iowa and one in central Iowa (Fig. 1). These prairies are: [1]Five Ridges prairie, Plymouth County; [2]Steele prairie, Cherokee County; [3]Cayler prairie, Dickinson County; [4]Freda Haffner Kettlehole, Dickinson county; [5]Anderson prairie, Emmet County; [6]Stinson prairie, Kossuth County; [7]Kalsow prairie, Pocahontas County; [8]Sheeder prairie, Guthrie County; [9]Doolittle prairie, Story County; [10]Cedar Hills sand prairie, Black Hawk County; [11]Hayden prairie, Howard County.

Results

Our total collections thus far in this project include about 200 fungi parasitic on over 130 species of prairie plants. The four groups of plants discussed in this paper include the most common species on many Iowa tallgrass prairies. Fungal parasites are presented for four common grasses (Table 1), five legumes (Table 2), seven common composites (Table 3), and nine common prairie species from several plant families (Table 4).

The fungi reported here include 43 species not reported in Gilman and Archer's 1929 report on the plant parasitic fungi of Iowa or in Gilman's later supplements (Gilman, 1932, 1949) to that report. An additional six fungus species are not included in those reports on the hosts on which we have encountered them but were listed on other plant hosts.

The data on fungal parasites presented here based on collections from common prairie plant species on the 11 Iowa prairies are typical of the information we have from these and additional hosts in other sites. The most common, potentially quite destructive, parasitic fungi on most grass hosts (Table 1) are the rusts. Two of these hosts, big bluestem and switchgrass, each had two different rust fungi on their leaves, a not unusual situation for the grasses. At least one rust was consistently present on three of the grass hosts by the end of the growing season on all prairies. The disease situation was different with Indian grass. A parasitic rust occurs on Indian grass leaves, but it is uncommon in Iowa. The most common and destructive pathogen on Indian grass is an imperfect fungus, *Stagonospora simplicior*, a leaf spot pathogen. This same fungus also produces characteristic large elliptical lesions with surrounding chlorotic tissue on leaves of big bluestem and little bluestem throughout the season. Tar spot develops on the leaves of big bluestem and little bluestem late in the season, usually in August.

Table 1. Fungal parasites of the most common tallgrass prairie grasses (Poaceae) of selected Iowa prairies.

Host & Fungus	Prairies 1	2	3	4	5	6	7	8	9	10	11
Andropogon gerardii (big bluestem)											
Rusts											
Puccinia andropogonis	x	x	x	x	x	x	x	x	x	x	x
Uromyces andropogonis					x						
Smuts											
Sphacelotheca occidentalis	x	x	x	x			x				
Ergot											
Claviceps purpurea								x			
Tar spot											
Phyllachora luteo-maculata	x	x	x	x		x	x	x	x	x	x
Leaf Spots											
Ascochyta agropyrina					x						
Ascochyta brachypodii	x					x					
Ascochyta sorghi	x										
Colletotrichum caudatum	x	x									
Colletotrichum graminicola							x				
Septoria andropogonis						x		x			
Stagonospora simplicior	x	x	x	x	x	x	x	x	x	x	x
Sphaerellopsis filum (On *Puccinia andropogonis* pustules)	x										
Schizachyrium scoparium (little bluestem)						a		a			
Rust											
Puccinia andropogonis	x						x	x		x	x
Tar spot											
Phyllachora luteo-maculata	x	x									x
Leaf spots											
Colletotrichum caudatum					x			x			
Colletotrichum graminicola			x					x			x
Stagonospora simplicior	x		x	x	x		x	x		x	
Sphaerellopsis filum (On *Puccinia andropogonis* pustules)								x			
Sorghastrum nutans (Indian grass)											
Leaf spots											
Colletotrichum caudatum		x		x		x	x			x	
Pseudoseptoria donacis				x							
Stagonospora simplicior	x	x	x	x			x			x	
Panicum virgatum L. (switchgrass)											
Rusts											
Puccinia emaculata		x		x		x		x		x	
Uromyces graminicola				x	x	x	x				x
Leaf spots											
Colletotrichum graminicola		x	x	x	x	x	x		x	x	x
Elsinoe panici	x	x	x	x		x	x		x	x	

a = host plant not collected

Even though the black sclerotia of ergot are common in the florets of open-pollinated grasses such as western wheat grass, rye and brome, this disease is seldom present on the tallgrass prairie grasses. It has been collected once during this project, on big bluestem at Sheeder prairie.

Although the smut fungi have been significant destructive parasites on agronomic grasses, the only smut fungus recorded on the native prairie grasses in this report is kernel smut of big bluestem, *Sphacelotheca occidentalis*. It occurs only in the native prairies of the northwestern portion of the state, although it is also present on planted prairies elsewhere in the state. Another smut of big bluestem, *Sorosporium provinciale*, is present on native prairies only in southern Iowa and destroys the entire inflorescences of diseased host plants.

Leaf spots, usually caused by species of imperfect fungi, occur on all of the prairie grasses. Some fungus species can parasitize several grass hosts, such as *Stagnospora simplicior* on leaves of Indian grass, big bluestem, and little bluestem (Table 1). Conversely, *Elsinoë panici* is a destructive leaf pathogen only on switchgrass. It does not parasitize other prairie species of *Panicum*, but can be lethal for its switchgrass host.

Table 2. Fungal parasites of common legume (Fabaceae) hosts of selected Iowa prairies.

Host & Fungus	Prairies 1	2	3	4	5	6	7	8	9	10	11
Amorpha canescens (lead plant)									a	a	
Rust											
Uropyxis amorphae	x				x	x	x	x			x
Desmodium canadense (tick-trefoil)											
Rust											
Uromyces hedysari-paniculati		x	x		x	x	x			x	x
Powdery mildew											
Microsphaera diffusa		x	x		x					x	x
Black mildew											
Parodiella hedysari		x				x	x				
Leaf spots											
Cercospora desmodiicola		x			x	x	x	x			
Gloeosporidiella desmodii							x				
Phyllosticta desmodii					x	x					
Ramularia desmodii						x	x		x		x
Sphaerellopsis filum (on *Uromyces hedysari-paniculati* pustules)						x					
Lathyrus venosus (bushy vetchling)	a					a		a	a	a	
Rust											
Uromyces fabae		x	x	x	x		x				x
Downy mildew											
Peronospora trifoliorum											x
Leaf spot											
Cercospora lathyrina					x						
Lespedeza capitata (bush clover)	a			a	a	a			a		
Rust											
Uromyces lespedezae-procumbentis			x				x			x	x
Tar spot											
Phyllachora lespedezae										x	x
Pediomelum argophyllum (scurf pea)	a						a	a	a	a	a
Rust											
Uromyces psoralea var. *argopyllae*		x	x			x	x				
Leaf spot											
Colletotrichum psoraleae			x	x	x	x					

a = host plant not collected

Rusts, species of *Uromyces* and *Uropyxis*, are the commonest parasitic fungi on the legume hosts (Table 2). *Lathyrus venosus* often is damaged severely by the extensive development of rust by mid-summer. However, two leaf-surface inhabiting fungi are the most destructive on tick-trefoil. Powdery mildew, characterized by a grayish-white covering of fungus mycelium on the leaf surfaces, and black mildew, with a jet black, external, leaf covering, may severely inhibit the development of young leaves and stems. The resulting dwarfed plants struggle to survive.

Table 3. Fungal parasites of most common composite hosts (Asteraceae) of selected Iowa prairies.

Host & Fungus	Prairies 1	2	3	4	5	6	7	8	9	10	11
Artemesia ludoviciana (prairie sage)											
Rust											
Puccinia similis			x	x						x	x
Leaf spot											
Nematostoma occidentalis	x	x	x	x	x	x	x	x	x	x	x
Aster simplex (panicled aster)	a		a	a						a	
Rusts											
Coleosporium asterum		x			x			x			x
Puccinia cnici-oleracea		x						x	x		x
White smut											
Entyloma compositarum						x					
Powdery mildew											
Erysiphe cichoracearum		x						x			
Leaf spots											
Ascochyta compositarum		x			x			x	x		
Cercosporella virgaureae								x			
Placosphaeria haydeni						x	x				x
Septoria atropurpurea					x	x					x
Coreopsis palmata (prairie coreopsis)	a						a		a	a	
Leaf spots											
Cercospora coreopsidis						x					x
Phyllosticta coreopsidis			x	x							
Septoria coreopsidis		x	x		x			x			x
Helianthus grosseserratus (sawtooth sunflower)	a										
Rust											
Puccinia helianthi		x	x	x	x	x	x	x	x	x	x
Downy mildew											
Plasmopara halstedii									x		x
Powdery mildew											
Erysiphe cichoracearum		x	x				x			x	
Leaf spots											
Colletotrichum helianthi								x			
Septoria helianthi						x					
Liatris aspera Michx. (rough blazing star)	a						a	a	a		
Leaf spot											
Septoria liatridis		x	x	x	x	x				x	x
Ratibida pinnata (grayhead coneflower)										a	
White smut											
Entyloma compositarum	x	x	x	x	x	x	x	x	x		x
Downy mildew											
Plasmopara halstedii								x			
Leaf spot											
Septoria infuscata								x			
Solidago canadensis (Canada goldenrod)	a							a			
Rust											
Coleosporium asterum		x	x	x		x	x			x	x
Leaf spots											
Ascochyta compositarum					x						
Cercospora stomatica			x						x		
Colletotrichum dematium		x									
Septoria virgaureae		x	x	x			x		x		x

a = host plant not collected

Rusts, caused by *Puccinia* and *Coleosporium* species, are common on the aster, sunflower, and goldenrod species presented here (Table 3). The same rusts, or other species in these genera, also are common on the other aster, sunflower, and goldenrod species of these prairies. The other composite hosts in Table 3 have a different range of common fungus parasites. White smut, a leaf spot smut causing white to yellowish spots, was present wherever grayhead coneflower was observed. It occurs throughout the season, but the round to oval white spots are not well delimited and are less obvious early in the season. *Nematostoma occidentalis*, identified in Table 3 as a leaf spot, is an ascomycete that develops black superficial ascocarps on the leaves of prairie sage. They could be interpreted easily as ascocarps of a powdery mildew, but the fungus does not develop the surface white mycelium of a powdery mildew. The black ascocarps may develop in sufficient number to impart a characteristic dark gray color to the leaves. These diseased leaves also may be less than normal size.

The miscellaneous species of common prairie plants summarized in Table 4 often are parasitized by rusts, usually by *Puccinia* species. Rose leaf rust, *Phragmidium rosae-arkansanae,* is very common on wild rose species. Indefinite chlorotic areas develop on the upper leaf surface as orange powdery pustules of urediospores and superficial clusters of black teliospores are formed on the lower leaf surface. The other common rose rust, *Phragmidium speciosum,* is evidenced by orange pustules of spores on the leaves or fruits in early summer and extensive black crusts of teliospores on the stems later in summer or early fall. Leaf spots also are common on rose.

Leaf spot fungi are the most frequently encountered parasites on the anemones, but *Puccinia anemones-virginianae,* a rust characterized by mounds of dark teliospores on the leaves, is expected by mid-summer.

The rusts on common milkweed and on bastard toadflax are evidenced in late May or June by clusters of white-rimmed, orange, spore-producing structures (aecia) on the leaves. These occur in spots on the leaves and are followed by killing of portions of the leaf or entire leaves. These rusts develop on the alternate grass hosts later in the summer, forming different spore-producing structures on the grass host. For example, *Puccinia andropogonis* produces clusters of cup-like orange structures (aecia) on bastard toadflax in early summer, then later produces pustules of orange-red spores (uredia) and eventually black spores (telia) on the leaves of big bluestem and little bluestem.

Powdery mildew, *Erysiphe cichoracearum*, often is well developed on leaves of wild bergamot, the superficial mycelium giving the leaves a gray color and a powdery appearance. The most common fungus parasite on rattlesnake master is *Cylindrosporium* leaf spot. The rectangular elongate spots may eventually coalesce, resulting in major destruction of leaf tissue as the season progresses.

Table 4. Fungal parasites of common prairie plant hosts (various families) of selected Iowa prairies.

Host & Fungus	1	2	3	4	5	6	7	8	9	10	11
Anemone canadensis (Canada anemone)	a							a		a	
Rust											
Puccinia anemones-virginianae					x						x
Downy mildew											
Plasmopara pygmaea		x			x	x					x
Leaf spots											
Phleospora anemones		x			x	x			x		
Ramularia didyma		x	x	x		x	x				x
Anemone cylindrica (thimble weed)		a			a				a		
Rust											
Puccinia anemones-virginianae	x					x	x			x	x
Leaf spots											
Phleospora anemones	x		x	x		x	x	x			
Phyllosticta anemonicola											x
Septoria anemones						x					
Asclepias syriaca (common milkweed)					a			a		a	
Rusts											
Puccinia chloridis	x					x					
Puccinia seymouriana		x		x					x		x
Leaf spots											
Cercospora clavata	x	x	x			x	x		x		
Cercospora venturioides				x		x					x
Colletotrichum fusarioides		x									
Comandra umbellata (bastard toadflax)											
Rust											
Puccinia andropogonis	x	x		x	x	x	x	x	x	x	x
Leaf spot											
Cercospora comandrae	x					x					
Eryngium yuccifolium (rattlesnake master)	a			a	a				a	a	
Leaf spots											
Cylindrosporium eryngii		x	x			x	x	x			x
Septoria eryngicola						x					
Monarda fistulosa (bergamot)		a			a		a				a
Rust											
Puccinia menthae			x			x		x			
Powdery mildew											
Erysiphe cichoracearum	x		x	x		x		x		x	
Leaf spot											
Ramularia brevipes						x					
Phlox pilosa (prairie phlox)	a									a	
Rust											
Uromyces acuminatus						x	x	x	x		x
Leaf spots											
Ascochyta phlogis			x								
Cercospora omphacodes		x		x	x	x	x	x	x		x
Septoria phlogis						x					
Rosa arkansana (rose)											a
Rusts											
Phragmidium rosae-arkansanae		x	x	x	x	x	x	x		x	
Phragmidium speciosum			x			x	x	x	x		
Leaf spots											
Cercospora rosicola	x	x	x	x	x	x		x	x	x	
Discosia artocreas					x	x					
Marssonina rosae							x				
Seimatosporium discosioides		x									
Zizia aurea (golden alexanders)	a				a					a	
Leaf gall											
Physoderma pluriannulatum							x		x		x
Leaf spots											
Cercospora ziziae		x	x	x		x	x	x	x		x
Septoria ziziae		x									
Stagnospora thaspii		x						x			

a = host plant not collected

Discussion

Parasitic fungi have long been recognized as significant factors in the establishment, survival, growth, and yield of cultivated plants. However, little attention has been given to fungi as factors in these critical events for native plants (Burdon, 1987). Fungi, usually those species already present in the soil, may interfere with plant establishment by causing seedling damping-off or root rots. We have not attempted to consider these fungi or other fungi associated with underground plant structures in the research project discussed in this paper.

Fungi may affect the survival of individual plants or alter their competitive ability. Leaf spots may cause immediate necrosis of leaf tissue, resulting in significant loss of photosynthetic tissue. The effects of tar spot fungi, leaf smuts, powdery mildew, and rusts may be more subtle and less immediately expressed. When the rusts produce spores in local pustules, the leaf epidermis and cuticle are broken, causing an immediate effect on transpiration rates.

Still other fungi may interfere with reproduction of the diseased plants. *Epichloe typhina* mycelium may invade the apical meristem of host grass species so that the inflorescence does not develop; which is the disease situation referred to as choke (Webster, 1980). Mycelium of *Claviceps* species, ergot, invades individual florets of grasses or sedges, replacing the ovary with a mass of fungus tissue that develops as a hard black sclerotium (Webster, 1980). Smut fungi that replace individual florets or entire inflorescences are common parasites on the grasses. These smut fungi may be perennial in their grass hosts, destroying floral tissue each year (Snetselaar and Tiffany, 1990, 1992).

As more complete information becomes available about the presence and incidence of these fungi (Tiffany et al., 1990), we can begin to evaluate their influence on competitive ability and survival of their host plants and interactions with the numerous other factors that will determine successful establishment and persistence of prairie plants. Resistance to penetration and subsequent establishment of a fungus in a host plant certainly is influenced, if not prevented, by the genetic components of the plant. Over the hundreds of years that prairie communities have been in existence with ongoing and various biological and environmental interactions, genetically susceptible individuals have consistently been at a disadvantage for survival or reaching reproductive maturity.

Plant-fungal disease interactions are constantly changing. As more virulent strains of fungal pathogens develop or as new fungi are introduced into an area, competitive abilities of the host plants may be altered. For example, kernel smut of big bluestem in Nebraska was reported by Dunleavy (1956). It was first observed in Iowa in 1978 on Cayler Prairie in the northwest part

of the state (Knaphus and Tiffany, 1986). As reported in Table 1, it has now been observed in prairies throughout the northwest portion. Kernel smut on big bluestem has been observed in new prairie plantings in other areas of the state, where this fungus does not occur on big bluestem on native prairies. Mycelium of kernel smut is perennial in the diseased plant and affects not only floral production but also vegetative vigor of the plant (Snetselaar and Tiffany, 1991). The impact of this fungus on its host population in Iowa prairies is still incompletely understood.

As we establish a more complete record of the fungus parasites on plants of individual prairies, we may be in a position to use this information to develop maintenance strategies that will control them or minimize their impact, particularly on our small, widely separated, remnant prairies. At the least, we will have information on another component involved in the dynamic mix of biological and environmental factors that shape our prairies.

Literature Cited

Burdon, J. 1987. Diseases and Plant Population Biology. Cambridge University Press, London. 208 pp.

Cummins, G.B. 1971. The Rust Fungi of Cereals, Grasses and Bamboos. Springer-Verlag, New York, NY. 570 pp.

Cummins, G.B. 1978. Rust Fungi of Legumes and Composites in North America. University of Arizona Press, Tucson, AZ. 424 pp.

Davis, J.J. 1903. Third supplementary list of parasitic fungi of Wisconsin. Transactions of the Wisconsin Academy of Science 14:83-106.

Davis, J.J. 1926. Notes on parasitic fungi in Wisconsin XII, XIII, XIV. Transactions of the Wisconsin Academy of Science 22:155-192.

Dunleavy, J. 1956. Kernel smut of big bluestem. Phytopathology 46:116-120.

Farr, D.F., G.F. Bills, G.P. Chamuris and A.Y. Rossman. 1989. Fungi on plants and plant products in the United States. Publ. no. 5, Contributions from the U.S.

National Fungus Collections. American Phytopathological Society, St. Paul, MN. 1252 pp.

Fischer, G.W. 1953. Manual of the Northern American Smut Fungi. Ronald Press, New York, NY. 343 pp.

Frankland, J.C., J.N. Hedger and M.J. Swift. 1982. Decomposer Basidiomycetes: Their Biology and Ecology. Cambridge University Press, London. 355 pp.

Gabel, A.W. and L.H. Tiffany. 1987. Life history of *Elsinoë panici*. Proceedings of the Iowa Academy of Science 94:121-127.

Gilman, J.C. 1932. First supplemental list of parasitic fungi from Iowa. Iowa State College of Journal of Science 6:357-365.

Gilman, J.C. 1949. Second supplementary list of parasitic fungi from Iowa. Iowa State College Journal of Science 23:261-272.

Gilman, J.C. and W.A. Archer. 1929. The fungi of Iowa parasitic on plants. Iowa State College Journal of Science 3:299-502.

Greene, H.C. 1940. Notes on Wisconsin parasitic fungi. I. Transactions of the Wisconsin Academy of Science 32:77-83.

Greene, H.C. 1968. Notes on Wisconsin parasitic fungi. XXXIII. Transactions of the Wisconsin Academy of Science 56:263-280.

Knaphus, G. and L.H. Tiffany. 1986. Kernel smut of big bluestem in Iowa. Proceedings of the Iowa Academy of Science 93:1 (Abstract).

Read, D.J., D.H. Lewis, A.H. Fitter and I.J. Alexander. 1992. Mycorrhizas in ecosystems. C.A.B. International, Wallingford, U.K. 419 pp.

Snetselaar, K. and L.H. Tiffany. 1990. Light and electron microscopy of sorus development in *Sorosporium provinciale*, a smut of big bluestem. Mycologia 82:480-492.

Snetselaar, K. and L.H. Tiffany. 1991. A Study of *Sphacelotheca occidentalis*, cause of kernel smut of big bluestem. Journal of Iowa Academy of Science 98(3):145-152.

Snetselaar, K.M. and L.H. Tiffany. 1992. Diseases of big bluestem caused by smut fungi. Pages 17-20. In: D.D. Smith and C.A. Jacobs (eds). Recapturing a Vanishing Heritage. Proceedings of the Twelfth North American Prairie Conference.

Sprague, R. 1950. Diseases of Cereals and Grasses in North America. (Fungi, except Smuts and Rusts). Ronald Press, New York, NY. 538 pp.

Trelease, W. 1884. Preliminary list of the parasitic fungi of Wisconsin. Transactions of the Wisconsin Academy of Science 6:106-144.

Tiffany, L.H., J.F. Shearer and G. Knaphus. 1990. Plant parasitic fungi of four tallgrass prairies of northern Iowa: Distribution and prevalence. Journal of the Iowa Academy of Science 97:157-166.

Webster, J. 1980. Introduction to Fungi, 2nd edition. Cambridge University Press, Cambridge. 669 pp.