The effect of altered rainfall patterns on leaf rust severity in tallgrass prairie

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Abstract

The altered precipitation patterns predicted by climate change models will likely affect the incidence and severity of plant disease in natural systems. We studied the effects of precipitation patterns on the pathogens of 23 common tallgrass prairie plant species at Konza Prairie Biological Station, finding a decrease in infection with decreasing precipitation for most, but not all, species. We studied in more detail the effects of precipitation patterns on leaf rust caused by *Puccinia dioicae* on goldenrod, *Solidago canadensis*, a common native forb. Precipitation is important for typical rust pathogens in two distinct seasons of the year. In spring, adequate leaf wetness duration is necessary for infection of the alternate host during a limited window of opportunity. In summer, greater numbers of intervals of adequate leaf wetness duration will allow for more generations of pathogen increase on the primary host, which allow for more spores to over winter.

Introduction

Changes in precipitation patterns may have important effects on plant pathogens in tallgrass prairie. Many foliar pathogens depend on leaf surface wetness for successful infection, but model predictions include reduced rainfall and greater intervals between rain events (Easterling 1990; Houghton et al. 1990, 1996; Karl et al. 1991). Two experiments at Konza Prairie Biological Station (KPBS) near Manhattan, Kansas, have been designed to study the long-term effects of altered patterns of precipitation on a mesic tallgrass prairie ecosystem (Fay et al. 2000). Plants may experience a trade-off as water becomes more limiting: they may experience water stress but they may also experience less infection by pathogens.

In our studies at KPBS so far, rust fungi have proven to be the most common foliar pathogens that produce clear visual symptoms. Many rust fungi have complex life cycles that include an alternate host where sexual reproduction takes place and a primary host where asexual reproduction takes place. The alternate host is infected in spring and the aeciospores produced on the alternate host can only infect the primary host. Urediniospores produced on the primary host can reinfect the primary host species to produce multiple generations of infection over the course of the summer. As primary hosts begin to senesce, or if primary hosts experience stress, the rust fungi switch from producing urediniospores to teliospores, which cannot reinfect the primary host but are adapted to overwinter. (Arthur 1962). Because of this complex lifecycle, rust fungi require adequate moisture at two different important points in the year. In spring, adequate moisture is required for the one chance at sexual reproduction. In summer, the greater the period during which adequate moisture is available, the more generations of reproduction are possible. If plants experience extreme drought stress at any point in the summer, the fungi may switch to producing teliospores so that no more fungal generations are possible that year.

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Response of foliar disease severity of common tallgrass prairie species to water stress

An irrigation experiment at KPBS initiated in 1990 addresses the effects of steady high levels of moisture on prairie plants (Knapp et al. 2001). Paired irrigation and control transects span upland and lowland topographic positions in annually burned prairie. Irrigation is conducted following a protocol designed to offset potential water deficits based on the Penman-Monteith model estimates of evapotranspiration, natural precipitation inputs, and soil water potentials. We estimated foliar disease severity in the lowland transects of this experiment for a set of 23 common tallgrass prairie plant species (Table 1) in 2001, and ongoing sampling is in progress.

Some plant species had no foliar infection with clear visual symptoms. Many species were infected by rust fungi (Table 1). Disease severity for the majority of these host-pathogen combinations was lower in the absence of irrigation, though there were some exceptions (Fig. 1). Our ongoing work in this experiment will allow us to determine whether the exceptional host-pathogen combinations show a consistent difference in response to changes in precipitation. Different responses to changes in precipitation by different host-pathogen combinations may contribute to greater stability in productivity in response to environmental change for more diverse plant communities.

Species number	Host species measured	Common name	Pathogen	Potential alternate hosts of leaf rusts or pathogen type
1	*Ambrosia psilostachya*	Western ragweed	*Puccinia xanthii*	Autoecious
5	*Dalea candida*	White prairie clover	*Uropyxis petalostemonis*	Autoecious
6	*Solidago canadensis*	Canada goldenrod	*Puccinia dioicae*	*Carex* sp.
10	*Kuhnia eupatorioides*	False boneset	*Puccinia kuhniae*	Autoecious
11	*Amorpha canescens*	Leadplant	*Uropyyxis amorphae*	Autoecious
16	*Andropogon gerardii*	Big bluestem	*Puccinia andropogonis*	*Aesculus, Amphicarpaea, Andropogon, Apios, Aureolaria, Baptisia, Castilleja, Chelone, Comandra, Dalea, Desmodium, Lupinus, Mimulus, Orthocarpus, Oxalis, Penstemon, Polygala, Psoralea, Schizachyrium, Zanthoxylum*
17	*Andropogon scoparius*	Little bluestem	*Puccinia andropogonis*	same as above
18	*Sorghastrum nutans*	Indian grass	*Puccinia virgata*	Autoecious
19	*Panicum virgatum*	Switchgrass	*Uromyces graminicola*	sp. in Euphorbiaceae
23	*Sporobolus asper*	Rough dropseed	*Puccinia sporoboli*	sp. in Liliaceae
24	*Bouteloua curtipendula*	Sideoats grama	*Puccinia chloridis*	sp. in Asclepiadaceae
12	*Lespedeza capitata*	Round-headed prairie clover	*Phyllachora lespedezae*	Ascomycetes: Pyrenomycetes
20	*Dichanthelium oligosanthes*	Scribner's dichanthelium	*Colletotrichum caudatum*	Dueteromycetes: Coelomycetes

Table 1. Plant species studied in disease transects illustrated in Fig. 1, along with other potential primary and alternate hosts for the pathogen

Rainfall manipulation treatments			
Treatment	**Amount of Precipitation**	**Interval between Applications**	**Years**
Ambient	Natural Amount	Natural Amount	1999-2003
Drought	Decreased by 30%	Natural Interval	1999-2001
Increased interval	Natural Amount	Increased by 50%	1999-2003
Drought + increased interval	Decreased by 30%	Decreased by 30%	1999-2001

Table 2. Rainfall manipulation treatments in the RaMP project

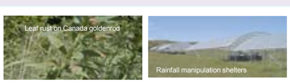

Fig. 4. Photos of Solidago rust and RaMP project

Effects of precipitation change on incidence of infection by the rust fungus *Puccinia dioicae*

We have studied *P. dioicae* for four years in the context of an experiment at KPBS designed to address the effects of decreased precipitation and increased intervals between precipitation events (Knapp et al. 2001). We estimated disease incidence in *Solidago canadensis* (Canada goldenrod), an alternate host of this pathogen that is infected in May. The primary hosts of *P. dioicae* include a number of *Carex* sp that are infected during the summer. Rainfall exclusion shelters were erected over 12 6x6 m plots (Fig. 4). The shelters were constructed with a steel tube frame and a transparent plastic roof. Each shelter had a rainfall collecting system, storage tanks and a sprinkler system for re-applying rainfall. Rainfall was collected and re-applied according to the protocol in Table 2. There were three replicates in a randomized complete block design.
We sampled three quadrats totaling 4 m^2 in each plot.

The treatments imposed in this experiment had varying effects during 2000-2004 (Fig. 5). In 2000, the pattern was as we might have expected and the differences were statistically significant ($p < 0.05$). In 2001 incidence was very low and no differences due to the treatments were observed; instead, there was some evidence in this year for an effect of primary host abundance within plots on incidence on *S. canadensis*. In 2002 disease incidence was very high and no treatment effects were observed; in this year replacement of the shelters in spring was delayed so some infection may have occurred before the shelters were in place. In 2003 incidence was again low and no clear treatment effect was observed.

We also considered the results in the untreated plots as a function of the ambient weather conditions over the four years (Fig. 6). We interpreted the precipitation pattern using the estimated LWD described above (Fig. 3). Based on the life cycle of *P. dioicae*, we would expect that two time segments are important to pathogen abundance. In May, the availability of more potential infection intervals should increase the success rate for infection of *Solidago* per propagule produced in the previous summer. The number of propagules available in May should be determined by the number and timing of potential infection intervals in the previous summer when *Carex* was infected. The years 2000, 2002, and 2003 had similar patterns of spring moisture availability and the differences in incidence were consistent with the differences in the number of potential weeks of pathogen population increase during the previous summer. In 2001 incidence was lowest of all; this year had the greatest number of potential weeks of pathogen population increase during the previous summer, but had the driest spring.

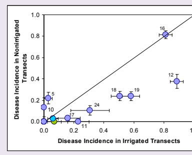

Figure 1. Pathogen load response to change in precipitation. Each point indicates the proportion leaves infected for a different core plant species (see Table 1 for species number key). Standard errors are indicated. Green dot is species number 1. Blue dot is species number 6.

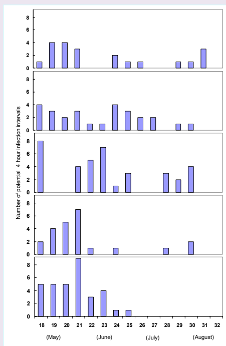

Figure 2. The number of potential infection intervals during the growing season for the Konza Prairie Biological Station in northeast Kansas (39°05'N, 96°35'W). Leaf wetness duration was estimated for pathogens requiring at least 4-hour intervals. (May = weeks 18-21 and summer = week 22-32)

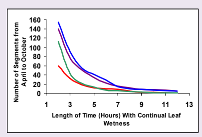

Figure 3. The estimated number of time intervals of sufficient leaf wetness occurring during the growing season at KPBS as a function of the minimum leaf wetness duration (LWD) required for infection. These four years illustrate the large variation in conduciveness of years, especially for pathogens with shorter LWD requirements

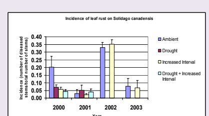

Figure 5. Disease incidence for Solidago canadensis in RaMPS treatments from 2000 to 2003. Bars represent the incidence on disease (number of diseased stems/total number of stems) ± standard errors. Note that only two treatments were applied in 2002-2003.

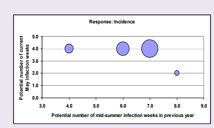

Figure 6. Disease incidence on Solidago canadensis (indicated by bubble size) as a function of the potential number of infection weeks in previous summer and current May.

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