Plant-pathogen interactions in an anthropogenic landscape: contrasting effects of undisturbed succession and mowing

Robert Doherty, Lauren Frazee, Jacquelyn Harth, and Janet Morrison
Department of Biology, The College of New Jersey, Ewing, NJ 08628
Authorship shared equally

Abstract

The warm season, perennial grass *Andropogon virginicus* (broomsedge) can dominate successional old fields in eastern North America, particularly on post-agricultural poor soils. It persists in communities with regular disturbance such as mowing; otherwise it decreases as woody vegetation increases. A survey of populations from Pennsylvania to South Carolina showed that 50% of populations were infected by the smut fungus *Sporisorium ellisii* (Basidiomycota, Ustilaginales), which decreases photosynthesis rate and host size, reduces/eliminates reproduction, and increases mortality. We have studied a 100 x 100 m section of an infected population since 2003, in order to understand host and pathogen population dynamics and their reciprocal influences. Disease rates declined from 2003 to 2006, while the plant community underwent succession without major disturbance. In the human-modified landscapes common to broomsedge, mowing is a frequent disturbance that may act to increase disease rates by spreading fungal teliospores, reducing woody competitors and increasing host density, and producing multiple wound sites for pathogen entry. We tested this idea by mowing three of five 20 x 100 m strips once in the study site in 2007, and then comparing changes in host size, density, and disease from 2006 to 2008, in the mowed and unmowed strips. Mowed plants were only 76% as tall as unmowed plants on average. Broomsedge density decreased and disease frequency increased across the site, with significant variation among strips, but independent of the mowing treatment. This suggests that environmental factors acting at the scale of 20 m may influence both host and pathogen dynamics more than does physical disturbance.

Andropogon virginicus spikelets. Left, healthy with seeds. Right, infected with the smut fungus *Sporisorium ellisii*, with teliospores in place of seeds.

Introduction

- *Andropogon virginicus* (broomsedge) is a warm-season, C_4 perennial grass that dominates the vegetation during early old field succession in the eastern United States, particularly on poor soils. Without regular disturbance such as mowing *A. virginicus* is typically replaced by woody vegetation.
- Populations often are found infected with the specialist smut fungus *Sporisorium ellisii*. This pathogen sporulates in the grass spikelets, eliminating seed production on infected tillers, and causing increased mortality. We studied an infected population of *A. virginicus* in central New Jersey from 2003-2006 without any disturbance, and observed a decrease in broomsedge density as succession proceeded, as well as a decline in disease rates.
- Mowing is a common disturbance in broomsedge populations, which inhabit roadsides, grasslands in managed natural area, and pastures. We hypothesized that mowing would increase the density of *A. virginicus* by reducing competition from woody vegetation, and that infection rates would increase due to the mechanical wounding of host plant tissue and dispersal of fungal teliospores. We tested these ideas with a mowing treatment applied in Fall 2007 and assessed in Fall 2008.

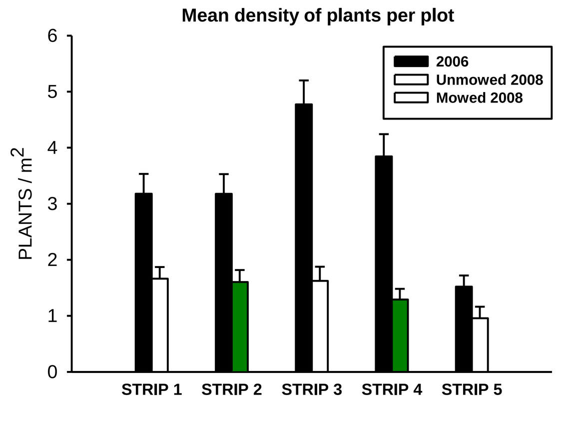
Methods

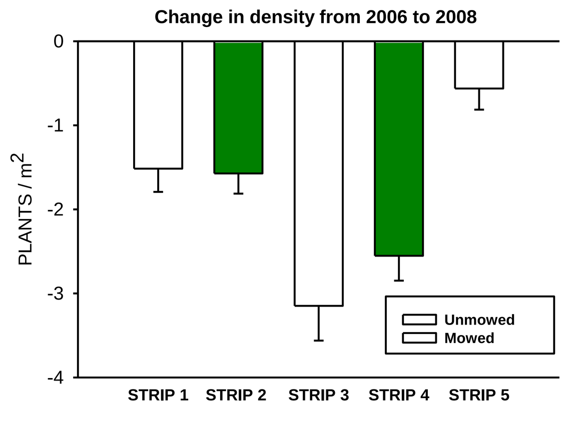
Study site :
An old-field plant community developing on fallow agricultural land in Mercer County Park Northwest, New Jersey, U.S.A. *A. virginicus* is a common species in the community, and infection by *S. ellisii* was very apparent throughout the population in 2003.
Sampling design :
480 1-m^2 plots in a systematic, repeating pattern of grouped plots throughout a 100 x 100 m section of land.
Mowing treatment :
Three of five 20 x 100 m strips were mowed by tractor once in Fall 2007, alternating with two unmowed strips.
Data collection :
Prior to treatment, 2006 – in each permanently marked 1-m^2 plot, measured density of healthy and infected *A. virginicus;* and, in plots with *A. virginicus* present, on a focal plant measured height, number of tillers, and infection status of each tiller.
Post-treatment, 2008 – Same measurements on the same plots as in 2006; focal plants were newly chosen, but included some from 2006 that survived the mowing treatment.
Data analysis :
Nested analyses of variance (strips nested within mowing treatments) on 2008 host density, change in host density, 2008 disease frequency, change in disease frequency, focal height, focal number of tillers. Chi-square test on treatment x focal disease status.

Results

Plots

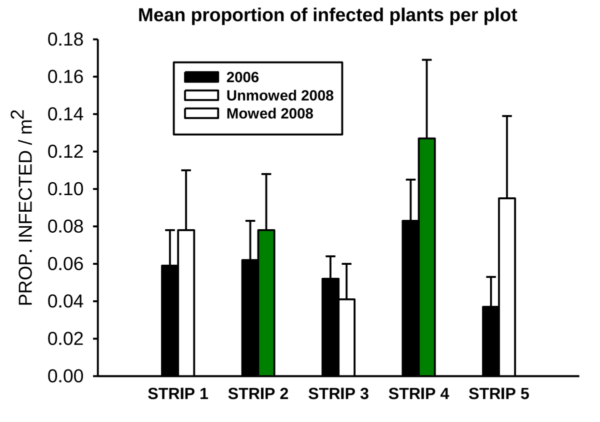
Mean plant density per plot decreased from 2006 to 2008, independently of the mowing treatment. However there was significant variability among the strips.

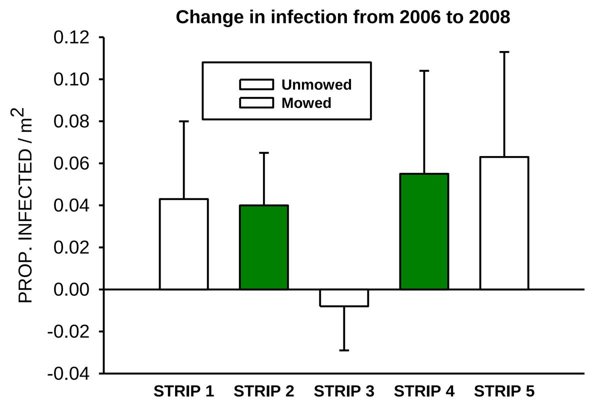




ANOVA: F_{mowing}=0.10, df=1,3, ns;
F_{strips}=14.28, df=3,466, P<0.001
(analysis for change in density)

Proportion of infected plants per plot increased in all strips but one from 2006 to 2008, independently of the mowing treatment.



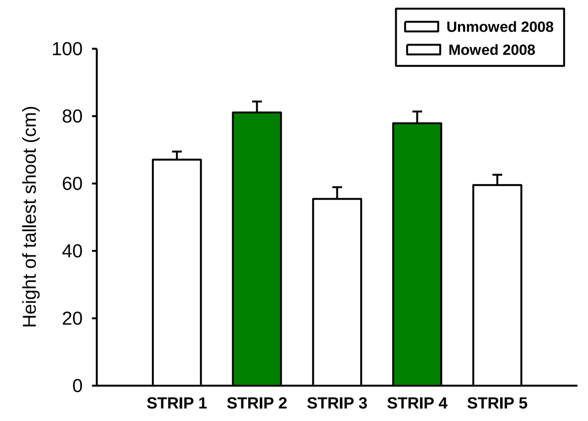


ANOVA: F_{mowing}=0.35, df=1,3, ns;
F_{strips}=0.56, df=3,215, ns
(analysis for change in infection)

Focals

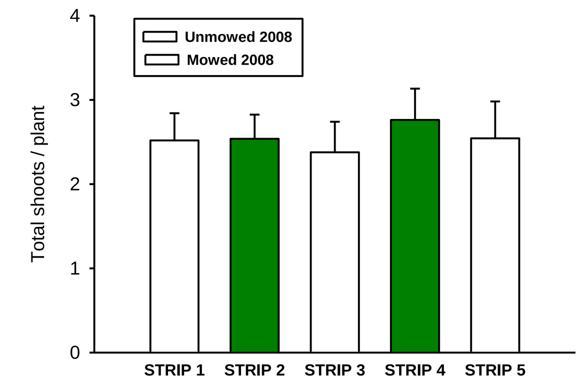
Plants in the unmowed strips were significantly taller than plants in the mowed strips.

ANOVA: F_{mowing}=15.92, df=1,3, P=0.0282;
F_{strips}=2.69, df=3,224, P=0.0472



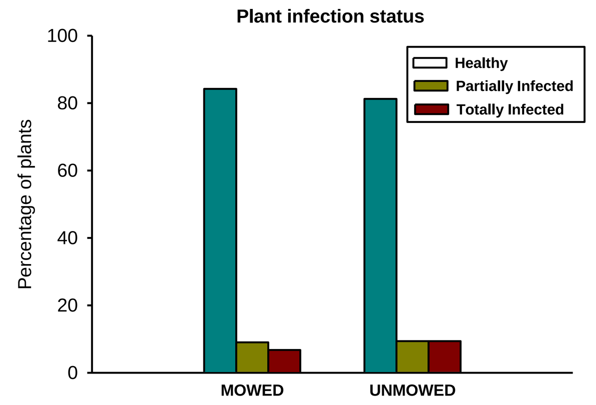
The total number of shoots per plant was unaffected by mowing.

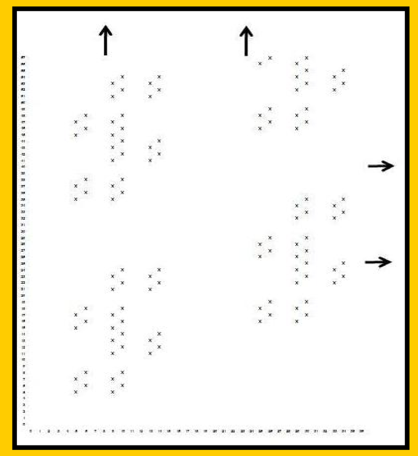
ANOVA: F_{mowing}=2.62, df=1,3, ns;
F_{strips}=0.11, df=3,217, ns



Percentages of healthy, partially infected, and totally infected plants were unaffected by mowing.

Chi-square = 0.59, df = 229, ns.





Spatial arrangement of 1-m^2 plots

Mowing design

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Discussion

Density: The single mowing treatment did not affect the host plants in the manner in which we predicted. Instead of increasing plant density by reducing competition and dispersing seed as predicted, mowing appeared to have no particular influence on broomsedge population density – it declined everywhere. Most likely the density decline in both treatments was due to a coincidence of two different processes; succession in the unmowed strips, and mortality from mowing plus a lack of rapid recruitment in the mowed strips. More time or a multi-year disturbance may be necessary to promote broomsedge density. The most variability was among strips, without regard to the mowing treatment. Curiously, some other factor that varies on the scale of 20 m (the strip width) drives broomsedge density more than the dramatic disturbance of mowing.

Disease: The mowing treatment also did not influence disease rates. Instead of increasing just in mowed plots, it increased in unmowed plots as well, and even decreased on average in one mowed strip. We observed no difference between the treatments for disease, either on the whole-plot level or the individual plant level. To explain this result, we can hypothesize that the smut fungus does not infect its host through wounded above-ground plant tissue, but rather enters by way of the roots or immature seed.

Both: The overall increase in disease prevalence across the entire population along with the overall decrease in host population density challenges the typical positive relationship posited between host density and disease. Based on previous work, it appears that host density and pathogen dynamics are decoupled in this plant pathosystem, with each more influenced by factors extrinsic to the density-disease relationship.