HAY-SCENTED FERN (*DENNSTAEDTIA PUNCTILOBULA)* AND SUGAR MAPLE *(ACER SACCHARUM)* SEEDLING OCCURRENCE WITH VARYING SOIL ACIDITY IN PENNSYLVANIA

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Abstract.—Hay-scented fern is an invasive species that has increased in abundance over the last half of the twentieth century. Since this species may limit woody regeneration, it is important for forest managers to understand why its prevalence is increasing. Eighteen sugar maple stands across Pennsylvania were sampled to determine if soil chemistry and canopy density played a role in the abundance of hay-scented fern. It was found that percent canopy cover and soil O-horizon Ca/Al ratios were negatively related to percent fern cover. Percent canopy cover was related to soil A-horizon pH. In addition, soil A- and B-horizon pH levels were related to sugar maple seedling presence. These results indicate that soil chemistry should be considered as a factor controlling hay-scented fern abundance and sugar maple regeneration in Pennsylvania.

Hay-scented fern (*Dennstaedtia punctilobula* (Michx.) Moore) is a rhizomatous fern commonly found in deciduous forests, old fields and roadsides in its native range of the Eastern United States and Canada. This invasive species is capable of growing in a wide range of light and soil conditions (Conard 1908, Cody et al. 1977, Burnside 1988) and often develops into mono-dominant stands. Once established, hay-scented fern inhibits woody regeneration (Horsley and Marquis 1983, Bowersox and McCormick 1987, Kolb et al. 1990, Horsley 1993) by outcompeting woody species for light (Horsley 1986, Burnside 1988, Kolb et al. 1990, Horsley 1993, Hippensteel and Bowersox 1995) and rooting space (Hammen 1993, Lyon and Sharpe 1996).

Hay-scented fern has apparently increased in abundance over the last half of the 20th century. Several possible explanations for the dominance of hay-scented fern on forest floors have been proposed. White-tailed deer (*Odocoileus virginianus virginianus* (Boddaert)) selectively browse many forest understory species, such as sugar maple (*Acer saccharum* Marsh), red maple (*Acer rubrum* L.), white ash (*Fraxinus americana* L.), yellow poplar (*Liriodendron tulipifera* L.), and eastern hemlock (*Tsuga canadensis* L.). These species can be reduced in abundance or eliminated by deer browse (Tilghman 1989). Deer generally do not browse the less palatable hay-scented fern; thus hay-scented fern may be at an advantage over more palatable species where deer are abundant, and especially in canopy gaps (Horsley and Marquis 1983, Collins and Pickett 1988).

Another possible explanation for hay-scented fern spread is soil acidification caused by acid deposition. Pennsylvania soils have become increasingly acidic over the last half of the twentieth century (Robert 1994, Drohan and Sharpe 1997). Soil acidification results in base cation leaching, elevated aluminum concentrations, and an imbalance of Ca/Al in soil solutions and in the rhizosphere. This imbalance inhibits Ca and Mg uptake, reduces fine root growth, alters photosynthetic activity, and leads to nutrient imbalances in forest tree species (Ulrich 1983, Zoettl and Huettl 1986, Godbold et al. 1988, Shortle and Smith 1988, Wright et al. 1989, Joslin and Wolfe 1992). On forested sites with very acid soils, soil acidity/nutrient status may limit regeneration of acid sensitive species such as sugar maple and lead to increased abundance of more acid tolerant species of plants that appear to be more adaptable to an acidifying edaphic environment. The proliferation of hay-scented fern in extremely acid soils appears to indicate its adaptability to such conditions. The objective of this study was to determine possible relationships between hay-scented fern frond density, percent hay-scented fern cover, soil acidity and canopy density.

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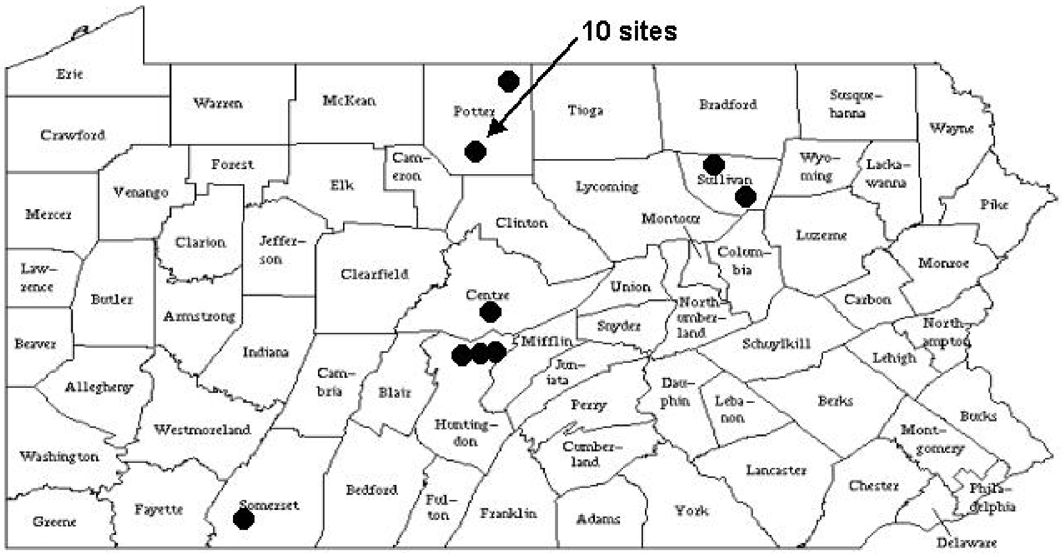

Figure 1.—General locations of the study sites.

Methods

Eighteen even-aged hardwood stands of predominantly sugar maple, located in Centre, Huntingdon, Potter, Somerset, and Sullivan Counties, Pennsylvania were selected for study (Figure 1). These stands were chosen to represent a gradient of soil acidity and Ca:Al values and the widest possible north-south distribution of sugar maple in Pennsylvania. Age of all stands was in the range of 80 to 90 years, and the stand size ranged from one to eight ha. Average dominant tree height for all stands (obtained through a subsample of at least five dominant trees per site) was 20.28 m and ranged from 13.20 m at site sixteen to 24.26 m at site five. Average dominant tree DBH for all stands (obtained from the same trees subsampled for height) was 36.25 cm and ranged from 25.03 cm for site sixteen to 50.58 cm at site seventeen. The stands were located in a variety of topographic locations, including stream bottoms, mid-slopes, and ridge tops in both the Valley and Ridge and Allegheny plateaus physiographic provinces.

Each stand was sampled to determine hay-scented fern percent cover, canopy density, sugar maple regeneration and soil chemistry. Random sampling of fern cover and sugar maple seedling occurrence was accomplished by throwing a hula-hoop from the center of each stand in a randomly selected direction. The 0.47-m^2 area described by the hoop when it landed was established as a sampling plot. Three such plots were established in each stand. Canopy density was determined from each plot location using a spherical densiometer. Fern fronds were counted and sugar maple seedling presence was assessed within the plots, and fern cover was visually estimated. Soil samples were collected from each plot from a small hand-excavated soil pit (40 cm deep). This depth ensured inclusion of the O, A, and B-horizons. Soil samples were extracted with 0.01 M $SrCl_2$ as a surrogate for plant available Al and Ca in each of the soil horizons (O, A, and B), and the molar Ca/Al ratio was calculated for each of the three horizons (Joslin and Wolfe, 1989). In addition, pH was determined in 1:1 water paste of air-dried soil. Linear and logistic regression techniques were used to analyze the data obtained.

Results and Discussion

The percent cover of hay-scented fern was strongly inversely related to percent canopy density of overstory sugar maple ($p \leq .001$) and O-horizon Ca/Al ratio ($p \leq .004$) in a linear regression model with a non-linear transformation. This linear regression analysis showed that canopy density and O-horizon Ca/Al ratio accounted for 71 percent of the variation in hay-scented fern cover (percent canopy density accounted for 53 percent of the variation and O-horizon Ca/Al ratio accounted for the remaining 18 percent of the variation in fern cover). Percent fern cover was negatively correlated with

Table 1.—Sugar maple seedling presence (1=present, 0=absent) and mean percent hay-scented fern cover, percent canopy density, A-, B-, and O-horizon soil pH, and A-, B-, and O-horizon Ca/Al ratio at each study site (ND – no data).

Site No	Sugar Maple Seedling Presence	Mean Percent Fern Cover	Mean Percent Canopy Density	Mean A Horizon pH	Mean B Horizon pH	Mean 0 Horizon pH	Mean A Horizon Ca/Al	Mean B Horizon Ca/Al	Mean O Horizon Ca/Al
1	0	0.25	0.90	4.74	5.12	5.54	22.56	0.33	147.11
2	1	0.00	0.97	5.18	5.10	4.90	627.15	129.13	1070.45
3	1	0.00	0.96	4.75	4.95	4.85	171.49	0.74	262.47
4	0	0.00	0.94	6.61	ND	ND	ND	ND	ND
5	1	0.00	0.94	5.13	5.02	4.57	2.78	5.11	206.70
6	1	0.00	0.91	4.68	5.24	4.45	106.00	331.15	2387.69
7	0	0.47	0.92	3.84	4.58	3.56	8.74	0.69	415.74
8	1	0.52	0.94	4.26	4.52	4.10	1.69	0.59	86.63
9	1	0.40	0.93	3.91	4.46	3.86	5.87	1.47	119.48
10	1	0.07	0.92	3.70	4.51	4.11	4.23	0.70	41.08
11	0	0.33	0.93	3.82	4.60	3.93	25.98	3.88	55.90
12	0	0.42	0.86	3.99	4.80	3.91	15.70	0.54	37.43
13	0	0.13	0.93	3.58	4.36	4.09	1.96	0.22	53.84
14	0	0.53	0.78	4.12	4.32	3.54	3.02	0.22	55.20
15	0	0.90	0.67	4.10	4.65	4.02	2.10	0.62	29.44
16	0	0.27	0.72	4.43	4.75	3.94	10.43	0.49	158.51
17	0	0.98	0.69	4.12	4.80	4.51	0.64	0.18	47.67
18	1	0.09	0.92	4.64	5.66	4.01	23.87	5.67	336.41

percent canopy density of sugar maple, which was expected because more sunlight was likely to reach the forest floor with reduced canopy density. Percent fern cover was also negatively correlated with O-horizon Ca/Al molar ratio. Percent canopy density and O-horizon Ca/Al data appear in Table 1.

In addition to the relationship between fern cover and O-horizon Ca/Al ratio, hay-scented fern frond density was found to be negatively related to the Ca:Al ratio in the A and B horizons (Figs. 2 and 3, respectively). A positive ($p \leq .057$) relationship was also present for percent canopy cover and A-horizon pH.

Sugar maple seedling occurrence, in relation to soil parameters and hay-scented fern occurrence, was analyzed by logistic regression. Results indicated that sugar maple seedlings were sixteen times less likely to occur on plots with hay-scented fern. However, sugar maple seedlings were four times more likely to occur with every unit increase in A-horizon soil pH and over six times more likely with every unit increase in B-horizon soil pH, within the pH ranges encountered in this study (pH range of 3.16-6.98 in the A-horizon and 4.22-5.91 in the B-horizon). Sugar maple seedling occurrence and corresponding B-horizon Ca/Al ratios are plotted in Figure 4. B-horizon Ca/Al ratio explained 55 percent of the variation in sugar maple seedling numbers on the study plots (Fig. 4).

Higher hay-scented fern densities were associated with reduced canopy density (which was correlated with low soil A-horizon pH levels) and low O-horizon Ca/Al ratios in sugar maple stands across Pennsylvania. Hay-scented fern appeared to be a superior competitor in the high light and low Ca/Al environments of extremely acid soils. Once established, hay-scented fern competes with other species for light and rooting space, which may further limit woody regeneration. These results indicate that soil acidity correction by liming may be required to regenerate sugar maple stands on strongly to extremely acid soils. The liming study of Wilmot et al. (1996) appears to support this hypothesis.

The data indicate that there is a strong association between soil acidity and both sugar maple canopy density and hay-scented fern abundance. This result is counter to the widely held notion (Marquis and

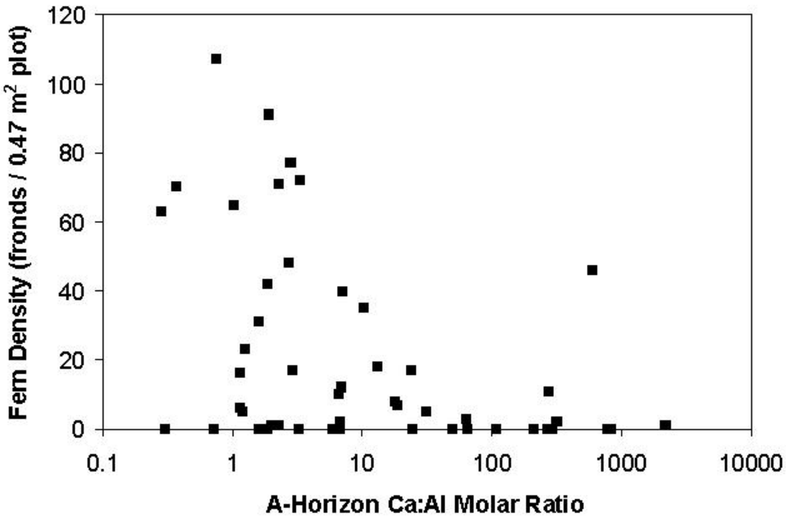

Figure 2.—The relationship between fern frond density and A-horizon Ca:Al molar ratio.

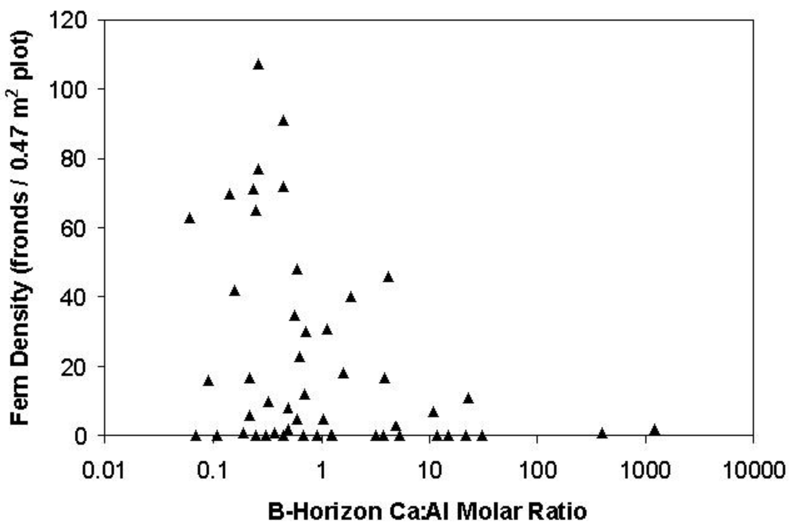

Figure 3.—The relationship between fern frond density and B-horizon Ca:Al molar ratio.

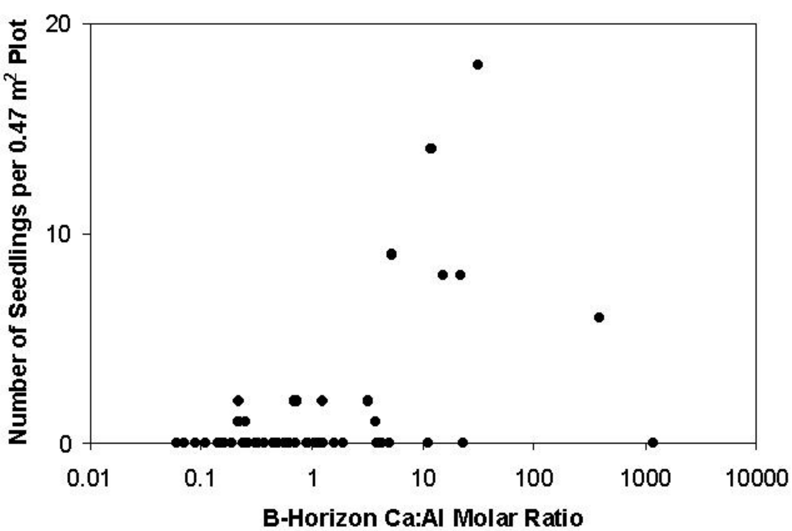

Figure 4.—Sugar maple seedling density versus B-horizon Ca:Al molar ratio.

Brenneman 1981, Horsley and Marquis 1983, Tilghman 1989) that hay-scented fern abundance is explained primarily by preferential browsing, which reduces competition from plants that are more palatable to white-tailed deer. It is also clear from the data presented that sugar maple seedling occurrence is associated with soil acidification on the sites that were studied. White-tailed deer numbers were not assessed in this study; however, the results represent data from 18 randomly selected sites across Pennsylvania, and we have no reason to believe background numbers of white-tailed deer differed in any more than a random way between sites. Further investigation into the relationship between hay-scented fern abundance, sugar maple regeneration, and edaphic conditions is needed.

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