COMPOSITION AND DEVELOPMENT OF NON-TREE VEGETATION AND ITS RELATIONSHIP WITH TREE REGENERATION IN MIXED-OAK FOREST STANDS

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ABSTRACT.— As part of a large-scale study of oak regeneration in Pennsylvania, non-tree vegetation was measured on 46 mixed-oak stands. Blueberry, hayscented fern, mountain-laurel, and huckleberry were, by percentage cover, the four most abundant non-tree species. After harvest, grasses, sedges, forbs, blackberry, and hayscented fern had pronounced expansion in non-herbicide treated stands. In the herbicide-treated stands, both hayscented fern and mountain-laurel abundance were significantly reduced after herbicide application. Regeneration density, survivorship, and growth rate were examined in different non-tree vegetation types. White oak regeneration was most abundant on subplots having moderate blueberry or huckleberry cover. Abundant chestnut oak tended to occur on plots with heavy cover of blueberry or huckleberry. High levels of red maple regeneration were commonly associated with moderate cover of hayscented fern.

Introduction

In the mixed-oak forests of Pennsylvania, dense ground covers of blueberry (*Vaccinium spp.*), hayscented fern (*Dennstaedtia punctilobula* (Michx.) Moore), and other non-tree species can interfere with the development of oak advance regeneration (Allen and Bowersox 1989, Steiner and Joyce 1999, Horsley et al. 1992). Hayscented fern has been classified as a competitor species because of its ability to respond aggressively to sudden resource availability with vegetative expansion of rhizomes and sexual reproduction (Groninger and McCormick 1991, Hughes and Fahey 1991). Blueberry, huckleberry (*Gaylussacia baccata* Wang.), and mountain-laurel (*Kalmia latifolia* L.) are common associates in oak forest understories in this region, and they differ considerably in how they influence regeneration and stand structure. This is partially due to the difference in height achieved by mountain-laurel compared to the relative low height of blueberry and huckleberry. Mountain-laurel, in particular, has created concerns regarding management for desirable tree seedlings in hardwood stands because of its aggressive vegetative growth habit (Moser et al. 1996). Although mountain-laurel has little effect on regeneration establishment, it does suppress the growth of small seedlings (Waterman et al. 1995). In light of the regeneration problem facing forest managers in Pennsylvania, there is a need to better understand the distribution and dynamics of competing species (McWilliams et al. 1995). This paper focuses on the distribution and development of the non-tree vegetation at a landscape scale and its association with the establishment, survivorship, and growth rate of advanced and post-harvest tree seedling regeneration.

Study Areas

The study includes 46 mixed-oak stands on a total area of 2069 acres across the Appalachian Plateau and Ridge and Valley physiographic provinces of Pennsylvania. Stand area varies from 15 to 80 acres with an average size of 45 acres. Prior to harvest, oaks (*Quercus* spp.) were the dominant species in all the stands included in this study. Soils in both provinces are derived from sandstone, siltstone, or shale and are typically well-drained and support moderately productive forests. Stand elevations range from 1,000 ft in the Ridge and Valley province to 2,400 ft on the Appalachian Plateau. Mean annual precipitation ranges from 38 to 45 inches and frost-free periods range from 140 to 160 days, both vary with elevation and topography (Cuff et al. 1989).

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Table 1.— Non-tree vegetation average percentage cover, occurrence frequency (percentage of subplots), and heavy-cover frequency (percentage of subplots with > 30 percent cover by species) in 46 mixed-oak forest stands prior to harvest.

Species	Avg. Cover (%)	Freq. (%)	>30 Freq (%)
Blueberry (*Vaccinium spp.*)	10.3	71.9	12.1
Bracken fern (*Pteriduim aqualinum*)	1.2	12.4	0.8
Forbs	0.2	39.5	0.1
Grass	0.7	17.6	0.7
Hayscented fern (*Dennstaedtia punctilobula*)	9.4	25.9	13.8
Huckleberry (*Gaylussacia baccata*)	5.1	21.8	7.3
Mountain-laurel (*Kalmia latifolia*)	8.8	29.3	12.5
Sedge	0.2	11.7	0.1
Teaberry (*Gaultheria procumbens*)	0.2	35.7	0.0
Witch-hazel (*Hamamelis virginiana*)	2.1	19.0	2.7

Methods

Field measurements in the 46 mixed-oak stands were performed during 1996 – 2002. All the stands were measured one year prior to harvest (clearcuts or shelterwoods), and 30 stands have been re-measured one year after harvesting. Depending on stand area, 15 to 30 twentieth-acre permanent plots (26.3 ft. radius) were systematically installed in a square grid to sample across the entire stand. Four permanent milacre subplots (3.72 ft. radius), were established within each plot. On each subplot, percentage cover of non-tree vegetation was estimated (in 5 percent increments) by species or species group, as was tree regeneration density and height by species. In total, 4830 pre-harvest subplots and 2898 one-year-after harvest subplots were included in this study.

Herbicide treatment was applied on 13 of the 46 stands, where hayscented fern densities appeared likely to inhibit tree regeneration. Six herbicide stands were re-measured one year post-harvest. Herbicide treatments were based upon the forester's management objectives for each stand and were not experimentally controlled. Stands were treated with herbicide if hayscented fern densities appeared likely to inhibit regeneration. OUST (sulfometuron methyl) or an ACCORD/OUST mix was applied to dense hayscented fern at various rates depending on fern density. The primary objective of the treatments was to establish and/or release desirable regeneration.

To assure a fair comparison of vegetation change before and after harvest, only 30 stands that were surveyed both before and after harvest are used. Those 30 stands were divided into two groups, non-herbicide and herbicide. The non-herbicide group included 24 stands (2273 subplots), and the herbicide group included 6 stands (625 subplots).

For the purpose of classifying, percentage cover of non-tree vegetation was grouped into four classes: none, low (1 to 10 percent cover), moderate (11 to 30 percent), and heavy (over 30 percent). The heavy class reflects the threshold level of competing vegetation considered problematic by Marquis (1994). Species frequency was obtained by counting all the subplots containing a given species and then dividing by the total number of subplots across all stands. Non-tree vegetation average percentage cover, occurrence frequency, and heavy-cover frequency (subplots with over 30 percent of cover by species) before harvest was calculated across all subplots. Regression analysis was performed between post-harvest non-tree cover and regeneration survivorship and percent growth. Percent growth is the relative change of cumulative height ((post-pre)/pre*100), where cumulative height was the total height of all the stems for species or species group on a subplot.

Results

Pre-harvest Species Composition and Distribution

Species with occurrence frequency over 10 percent are listed in Table 1. Blueberry was the most abundant understory vegetation species both in percentage of cover and occurrence frequency. On

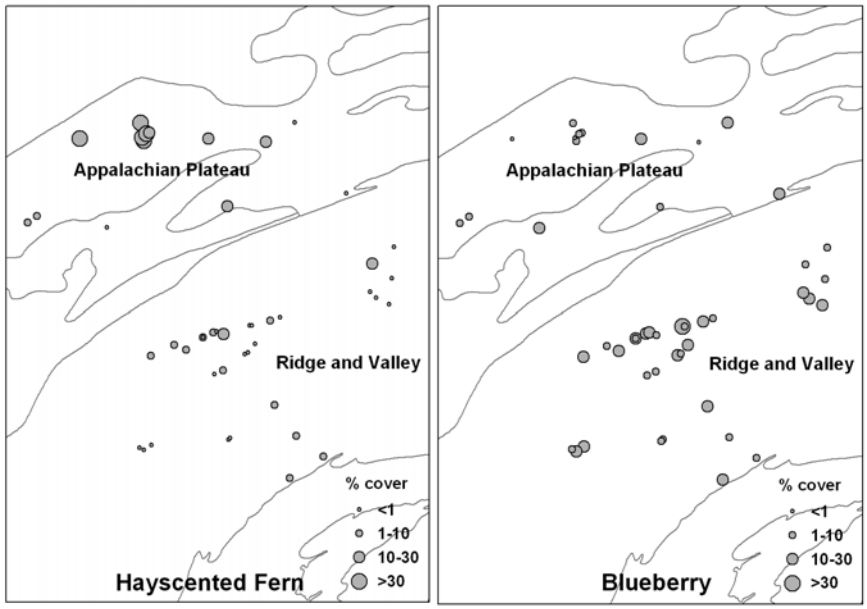

Figure 1.—Regional distribution of hayscented fern and blueberry average percentage cover prior to harvest.

average, blueberry covered 10.3 percent of the mixed-oak forest floor, and it was present in 71.9 percent of all the subplots. Hayscented fern was the second most abundant species (9.4 percent cover). Its occurrence tended to be the most concentrated; over half of the subplots in which it was present had above 30 percent cover. Mountain-laurel and huckleberry were the next two most abundant non-tree species by cover (8.8 and 5.1 percent, respectively). Heavy cover of hayscented fern, mountain-laurel, and blueberry all occurred on over 10 percent of all the subplots. Although low in coverage, forbs and teaberry (*Gaultheria procubens* L.) were the second and third most common species or species groups by frequency. They tend to occur "anywhere" but nowhere in great abundance.

Generally, prior to harvest, stands on the Appalachian Plateau had a higher percentage of hayscented fern cover than did stands in Ridge and Valley region (fig.1). However, there were three stands on the Plateau that had low fern cover and two stands in the Ridge and Valley that had moderate fern cover. Blueberry, on the other hand, was more abundant in the Ridge and Valley region than on the Plateau, but the difference was not as remarkable as for hayscented fern.

Vegetation Changes Pre- vs. Post-harvest

A comparison between non-tree vegetation before and after harvest is shown in Table 2. As mentioned, the stands in which herbicide was applied had high density of hayscented fern, so coverage by this species is an obvious and expected distinction between the two stand categories. Blueberry had the most abundant average cover in the non-herbicide group.

Considerable changes were observed in the non-herbicide stands one year post-harvest. Before harvest, blueberry, mountain-laurel, and huckleberry were the most abundant non-tree species, having average cover of 5 percent or more. One year post-harvest, however, only blueberry and hayscented fern retained over 5 percent cover. Meanwhile, hayscented fern occurrence frequency had a dramatic increase of almost three-fold compare to pre-harvest. Other herbaceous species and species groups, including forbs, grasses, sedges, bracken fern, and blackberry (*Rubus alleghaniensis*) also increased in cover and occurrence frequency. For mountain-laurel and huckleberry, the frequency of heavy-cover subplots was reduced one year after harvest.

Table 2.—Average non-tree vegetation percentage cover, occurrence frequency (percentage of subplots), and heavy-cover frequency (percentage of subplots with > 30 percent cover by species) before and one year after harvest in herbicide and non-herbicide stands.

Species	Avg. Cover (%)		Freq. (%)		Heavy-cover Freq. (%)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
			Non-herbicide treatment			
Blackberry	0.0	0.1	0.4	9.9	0.0	0.0
Blueberry	14.0	10.8	64.8	75.6	17.9	13.2
Bracken fern	0.2	0.6	2.1	5.7	0.1	0.7
Forbs	0.3	2.2	2.8	61.3	0.0	2.1
Grass	0.3	3.2	2.7	29.1	0.1	3.9
Hayscented fern	5.1	5.3	11.1	29.6	7.1	6.7
Huckleberry	7.6	3.1	26.3	21.3	11.4	3.8
Mountain-laurel	8.5	2.8	25.9	24.5	11.7	2.8
Sedge	0.3	1.7	2.5	17.0	0.1	2.1
Teaberry	0.1	0.1	0.9	32.2	0.0	0.0
Witch-hazel	2.7	1.0	11.0	17.0	3.6	1.0
			Herbicide treatment			
Blackberry	0.0	3.8	0.2	18.6	0.0	4.8
Blueberry	6.4	3.8	36.6	52.0	6.4	1.6
Bracken fern	1.7	0.3	10.7	10.1	1.9	0.3
Forbs	0.1	0.4	1.3	49.9	0.2	0.0
Grass	1.2	1.2	8.0	31.7	1.6	1.0
Hayscented fern	28.3	2.3	54.9	33.6	41.8	2.4
Huckleberry	0.5	0.6	2.2	11.7	1.0	0.6
Mountain-laurel	14.3	3.4	30.4	28.6	21.4	2.1
Sedge	0.3	0.5	2.7	22.1	0.0	0.0
Teaberry	0.1	0.3	1.6	25.4	0.0	0.0
Witch-hazel	2.6	1.1	7.0	10.9	3.8	1.8

In the herbicide stands, hayscented fern was reduced dramatically both in terms of cover (28.3 to 2.3 percent) and occurrence frequency (54.9 to 33.6 percent). In addition, subplots with a problematic level of fern cover were almost eliminated, which indicated that the herbicide treatments were successful. The herbicide treated stands also had a significant reduction of mountain-laurel, both in cover (14.3 to 3.4 percent) and heavy-cover frequency (21.4 to 2.1 percent).

Non-tree Vegetation Abundance vs. Regeneration Density

Interesting associations between non-tree vegetation density class and advanced regeneration density of tree seedlings were found across the study sites (fig. 2). The four most abundant non-tree species (i.e., blueberry, hayscented fern, mountain-laurel, and huckleberry) and four regeneration species (i.e., red maple (*Acer rubrum* L.), northern red oak (*Quercus rubra* L.), white oak (*Quercus alba* L.), and chestnut oak (*Quercus prinus* L.)) are presented for comparison.

Red maple regeneration was most abundant in association with low cover of mountain-laurel and moderate cover of hayscented fern, and regeneration was least abundant where coverage of both those species was heavy. Surprisingly, northern red oak was most abundant on plots with moderate hayscented fern cover and occurred at low abundance where hayscented fern was absent. Red oak regeneration density decreased as the cover of blueberry and huckleberry thickened. White oak was most abundant on plots with moderate cover of huckleberry and blueberry, and chestnut oak was most abundant on plots with moderate to high cover of those species.

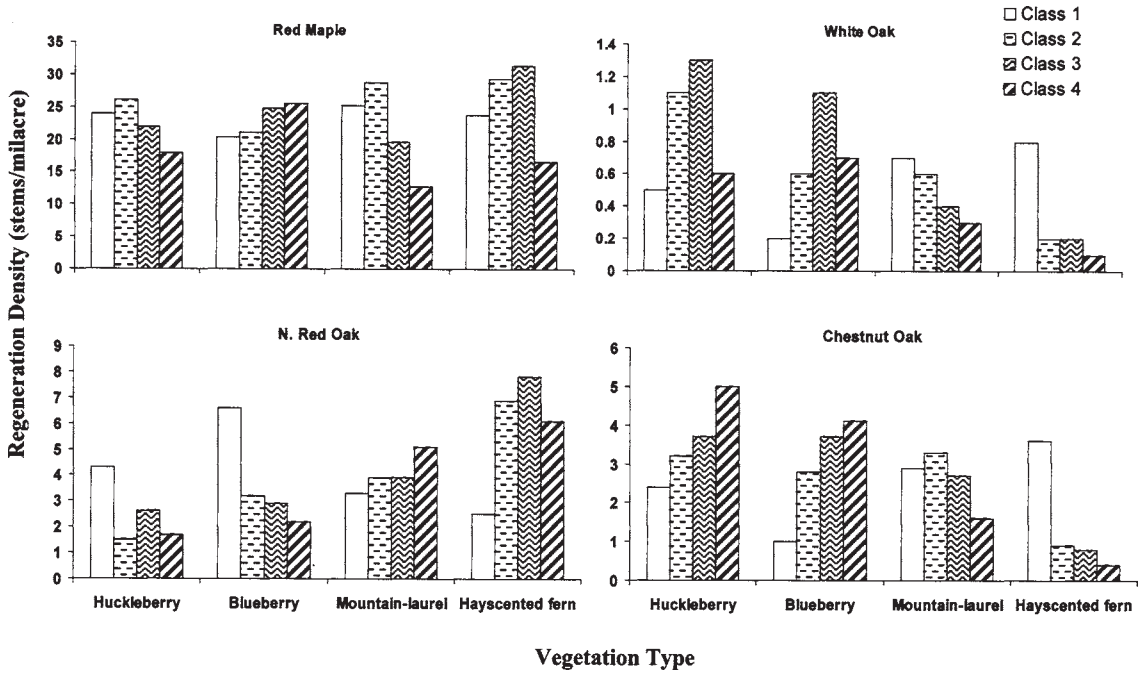

Figure 2.—Advanced regeneration density of four tree species under different cover classes (class 1: no cover; class 2: 1-10 percent; class 3: 11-30 percent; class 4: >30 percent) of four non-tree vegetation types.

No statistically significant relationships between vegetation type and coverage and regeneration survival rates were found. Nor were there any significant relationships between vegetation type and regeneration growth rate except for the relationship between red maple and blueberry (fig. 3). Percentage growth in cumulative height of red maple decreased as the blueberry cover increased ($p = 0.003$). If a stand had an average blueberry cover approximately over 10 percent, then the percent growth for red maple would be less than zero, which implies that red maple lost its density and cumulative height under those conditions.

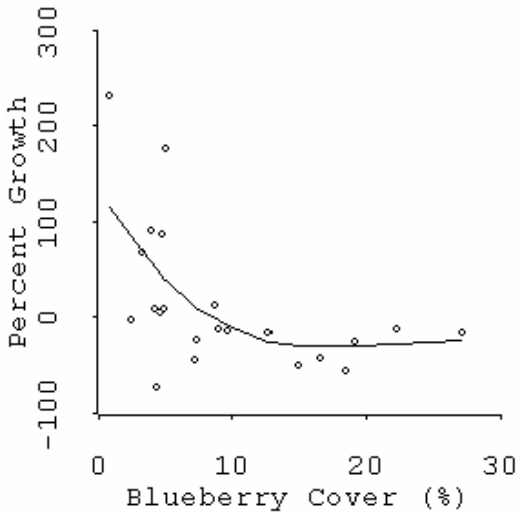

Figure 3.—Relationship between red maple percent growth in cumulative height ((post-pre) /pre*100) and average blueberry percentage cover in each stand.

Discussion and Conclusions

Blueberry was the most frequent non-tree species in the understory across all stands in the study area, and it was particularly common in the Ridge and Valley ecological province. Plots with moderate cover of blueberry and huckleberry had the most abundant white oak regeneration, and plots with heavy cover of blueberry and huckleberry had the most abundant chestnut oak regeneration. Rogers (1974) pointed out that heath communities dominated by blueberry and huckleberry have an affinity for infertile sites with well-drained acidic soils. The affinity of some oaks for similar environmental conditions may at least partially explain why regeneration of white oak and chestnut oaks was associated with blueberry and huckleberry. Blueberry and huckleberry had an average height of about two feet on our surveyed plots. Moderate to heavy cover of this low shrub layer might have reduced deer predation of acorns and small seedlings, therefore facilitating the establishment of oak regeneration.

Competition from hayscented fern has been identified as an important factor contributing to the regeneration problem in Pennsylvania (McWilliams et al. 1995). The abundance of hayscented fern in mixed-oak forest understories appears to suppress desirable tree seedlings by decreasing light quantity and quality beneath the herbaceous layer (Horsely 1993, George and Bazzaz 1999). In our study, herbicide treatment was an effective control of hayscented fern where it was used. But if herbicide was not used and hayscented fern was present, it spread both in cover and frequency following harvest. In addition, moderate levels of fern cover were associated with dense red maple regeneration. Similar association between fern cover and red maple basal area was also found in our recent research (unpublished). The combination of a dense fern cover and abundant red maple in both the overstory and understory will likely be detrimental to oak regeneration.

The co-occurrence of moderate levels of hayscented fern and high northern red oak regeneration is difficult to interpret. One possible explanation was that northern red oak can escape detection by deer under fern that helped its establishment, but neither white oak nor chestnut oak tends to occur where fern is common, and the maple doesn't matter because it is not a preferred deer food.

The following are our conclusions:

- In the mixed-oak forest in Pennsylvania, blueberry, hayscented fern, mountain-laurel, and huckleberry were the four most abundant species by cover.
- Hayscented fern was more abundant on the Appalachian plateau, while blueberry was more abundant in the Ridge and Valley ecological province.
- Red maple was most abundant on subplots with moderate levels of hayscented cover, while hayscented fern was negatively associated with both white oak and chestnut oak. Higher levels of blueberry and huckleberry were associated with higher density of oak regeneration.
- No significant relationships between non-tree species or species groups and regeneration survivorship and growth rate were identified, except there was a negative relationship between red maple growth rate and blueberry cover percentage.

Literature Cited

Allen, D. and Bowersox, T.W. 1989. **Regeneration in oak stands following gypsy moth defoliations.** In Proceedings of the Seventh Central Hardwood Forest Conference, Southern Illinois University, Carbondale. (G. Rink and C.A. Budelsky, eds.). pp 67-73. Gen. Tech. Rep. NC-132. USDA North Central Research Station, St. Paul, MN.

Cuff, D.J., Young, W.J., Muller, E.K., Zelinsky, W. and Abler, R.F., eds. 1989. **The atlas of Pennsylvania.** Temple University Press. Philadelphia, PA. 288p.

George, L.O., and F.A. Bazzaz. 1999. **The fern understory as an ecological filter: growth and survival of canopy-tree seedlings.** Ecology 80: 846-856.

Groninger, J.W. and L.H. McCormick. 1991. **Invasion of a partially cut oak stand by hayscented fern.** In Proceedings of the Eighth Central Hardwood Forest Conference, The Pennsylvania State University, University Park. (L.H. McCormick and K.W. Gottschalk, eds.) pp. 585-586. Gen. Tech. Rep. NE-148. USDA Northeastern Forest Experiment Station, Randor, PA.

Horsley, S.B., L.H. McCormick, and J.W. Groninger. 1992. **Effects of timing of oust application on survival of hardwood seedlings.** Northern Journal of Applied Forestry 9: 22-27.

Horsley, S.B., 1993. **Mechanisms of interference between hay-scented fern and black cherry.** Canadian Journal of Forest Research 23: 2059-2069.

Hughes, J.F. and T.J. Fahey. 1991. **Colonization dynamics of herbs and shrubs in disturbed northern hardwood forest**. Journal of Ecology 79:605-616.

McWilliams, W.H., Stout, S.L., Bowersox, T.W. and McCormick, L.H. 1995. **Adequacy of advance tree-seedling regeneration in Pennsylvania's forests.** Northern Journal of Applied Forestry. 12: 187-191.

Marquis, D.A. 1994. **Quantitative silviculture for hardwood forests of the Alleghenies.** Gen. Tech. Rep. NE-183. USDA Northeastern Forest Experiment Station, Randor, PA. 376 p.

Moser, K.W., M.J. Ducey, and P.M.S. Ashton. 1996. **effects of fire intensity on competitive dynamics between red and black oaks and mountain-laurel.** Nor. J. App. For. 13 (3): 199-123.

Rogers, R. 1974. **Blueberries** [**forest ranges**]. USDA For. Ser. Gen. Tech. Rep. NE-9:12-15.

Steiner, K.C. and B.J. Joyce. 1999. **Survival and growth of a *Quercus rubra* regeneration cohort during five years following masting.** In Proceedings of the Ninth Central Hardwood Forest Conference, University of Kentucky, Lexington. (J.W. Stringer and D.L.Lofts, eds.). pp. 255-57. Gen. Tech. Rep. SRS-24. USDA Southern Research Station, Ashville, NC.