1-1-1993

The Effects of Wildfire on the Herbaceous Layer of a Southwestern West Virginia Mixed Hardwood Forest

Michael K. Nowlin
MICHAEL.NOWLIN@wvinsurance.gov

Recommended Citation

Nowlin, Michael K., "The Effects of Wildfire on the Herbaceous Layer of a Southwestern West Virginia Mixed Hardwood Forest" (1993). *Theses, Dissertations and Capstones.* Paper 386.

The Effects of Wildfire on the Herbaceous Layer of a Southwestern West Virginia Mixed Hardwood Forest

by

Michael K. Nowlin

Department of Biological Sciences

Marshall University

This thesis was accepted on April 23 1993
Month Day Year

as meeting the research requirement for the master's degree.

Approved:

Frank S. Gilliam

Frank S. Gilliam, Chairman

Leonard J Deutsch

Leonard J. Deutsch
Dean of Graduate School

A thesis submitted in partial fulfillment of the
requirments for the degree of Master of Science in the
Department of Biological Sciences in
the Graduate School of Marshall University

ABSTRACT

The effects of fire on the mixed hardwood forests in West Virginia have long been of interest both biologically and economically. This study examined the effects of a Fall, 1991 wildfire in Wayne County, West Virginia on soil fertility and herbaceous layer response.

Fire intensity was determined by comparison of 1) remaining organic material, 2) understory survival and 3) height of charcoal on the stems of trees following the fire. Study plots were established in areas representing fires of high, moderate and low intensities with a control established in an adjacent unburned area of similar aspect and elevation.

Composite soil samples were taken from each site and analyzed at a soil testing laboratory for pH, cation exchange capacity and extractable ions including NO_3^-, NH_4^+, PO_4^{3-}, K^+, Ca^{2+} and Mg^{2+}. Soil texture was determined by the hydrometer method for each plot. Soil fertility response was evaluated with a plant bioassay experiment, using Poa pratensis (Kentucky bluegrass) grown in soil from each burn type and amended with a variety of nutrient solutions containing N, P, K, Ca and Mg present in full treatment. A seedbank study was performed to further assess potential herb layer recovery. Replicate sections of forest floor and surface soil were taken from each burn type and allowed to develop in the greenhouse with only periodic watering. Herbaceous layer and canopy cover measurements were made at each site during the spring, summer and fall of 1992. Overstory species were measured and importance values determined.

The bioassay suggested that soil fertility was increased by the fire in the burned plots. Nitrogen may possibly be the most limiting nurtient on all plots. The least fertile soils were found in unburned areas. There was a negative correlation between herbaceous cover and canopy opening. Herbaceous cover was greatest on high intensity burned plots and lowest on unburned plots. Both richness and diversity were greatest in the burned plots. Canonical discriminent analysis was performed using SAS CANDISC proceedures. Species composition over time varied most on low and high burned plots. The species composition of unburned and moderately-burned plots were most similar throughout the first growing season.

Species which developed in the seedbank study were generally well-represented in the herbaceous layer (80.6%). A few species which developed in the seedbank sample were not represented in the herbaceous layer. This suggests that the seedbank potential was limited to a degree in the herbaceous layer by some on-site factor(s).

It is suggested that herbaceous cover following burning is not determined by any single factor (fertility, canopy cover, etc.) but by a combination of all on-site factors. The highest herbaceous cover was found in areas of moderate fertility

increases following burning. This suggests that the increase in solar input as a result of canopy openings caused by the fire may be the most important factor in increasing herbaceous growth. This was not the case for low and moderately burned plots. Canopy cover was the same at the end of the growing season yet herbaceous cover was much greater at low burned plots. This may indicate that the interaction of factors which allowed for the greatest herbaceous cover were not the same at each plot.

ACKNOWLEDGEMENTS

The author wishes to acknowledge all who have provided assistance toward the completion of this thesis. This privilege is not often extended. I feel compelled to mention several individuals, whom although not directly associated with this work, provided me at one time or another the incentive, as well as the tools required to bring me to this point.

I want to express my profound thanks to Dr. Frank Gilliam, my committee chairman during my time spent at Marshall. Without his assistance and guidance this work would not have been possible. His knowledge of the literature and current fire ecology topics have been instrumental. The number of drafts reviewed has not been few. The valuable suggestions provided as a result of the reviews, as well as many other casual meetings, have been genuinely appreciated.

I also wish to thank Dr. Thomas Weaks, another member of my graduate committee. His encouragement and support have been a constant during my graduate work. His character, reason and demeanor has been an inspiration.

Thanks are also extended to committee member Dr. Dan Evans. His assistance in identifications for both the seedbank samples and field unknowns was instrumental toward the completion of this work. His taxonomy instruction has made my time afield more interesting and enjoyable.

I also wish to thank Dr. Rose-Marie Muzika for consenting to serve as my fourth committee member. Her expertise in forest ecology and familiarity with the literature has been a great assistance in shaping this work. Her review of my first draft also must receive recognition. I am very proud and pleased to have a USFS research ecologist involved with my thesis. Her enthusiasm, encouragement and support have been greatly appreciated.

Thanks must be extended to Dr. Ray Hicks at WVU for the loan of the densiometer used during the course of this study. I also wish to acknowledge the support of Dr. Bonnie Dean at WV State College and Dr. Ken Carvell, WVU (retired). The encouragement for this undertaking will never be forgotten.

I also want to take this opportunity to thank my fellow graduate students for their friendship and support during my time at Marshall. I am proud to be associated with the group as a whole and I wish all happiness in their personal endeavors.

I would be remiss in my thanks without acknowledgement of the efforts of Mr. Donald R. Nash. He has been instrumental with field identifications and without his assistance this work could not have been accomplished in a timely fashion. His assistance in all phases of the work accomplished in the field is genuinely appreciated. I am pleased not only to have shared his companionship afield, but also his friendship.

My thanks must next be extended to my parents, A.K. and Avon Nowlin. I am sure that many days were spent afield camping or hunting with me during my younger years when you would have preferred to be home relaxing or working on your latest project. Spending time with you at my Uncle Carlton's camp on the Greenbrier River are among my fondest childhood memories. These are savored and will never be forgotten. Your encouragement and support of my education, your kindness, thoughtfulness, work ethic and love has most certainly made this thesis possible.

Thanks must also be extended to my in-laws, Ralph and Barbara Miller. Ralph's knowledge of the forest and woodcraft has played a large part leading to current interests. Your knowledge of the traditional Applachain lifestyle has provided reflection during many quiet evenings. Many memorable hunting camps have been shared in the past and will not be forgotten by any who were fortunate enough to be present. Your interest in conservation and management of our natural resources has provided a personal touchstone in my activities afield. From this perspective, this work would not have been possible without you.

Finally, I wish to extend my most profound thanks to my wife, Debra and son, Jason. Many times your faith in me has been far greater than my own. Few families have had to stand the test we faced together. We have stood together in the best and the worst of times. It is rare to have such true and unwavering support one for the other. For this, and much more I am grateful.

For my son Jason, I wish happiness and health. It seems that true happiness is pursued by many and found by only a few. So many times the situation is confounded by one's inability to recognize happiness when it presents itself. It is my hope that you will have the wisdom to not only recognize it, but also the capacity to enjoy it for the remainder of your days.

To my wife Debra, my most profound thanks are offered. Ours has been an enduring friendship spanning more than two decades at this point. It is my wish that these years represent only the beginning of a long partnership. Many have spent lifetimes trying to find simple things like the love, support and respect we share everyday. We are fortunate in this regard, and I am quite grateful. Her support for my academic endeavors has been greatly appreciated. For these and many more reasons, this thesis would not have been possible without her.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

The Effect of Wildfire on the Herbaceous Layer of a Southwestern West Virginia Mixed Hardwood Forest

I. INTRODUCTION

Fire has been a dominant factor in shaping plant communities (Spurr and Barnes, 1980). Fire has been more or less frequent in all forest ecosystems except for the rain forests in southeastern Alaska, coastal northwest Europe, and the wettest belt in the tropics (Spurr and Barnes,1980). Periodic fire has contributed to the dominance of oak (Quercus) in the eastern deciduous forest (Abrams and Nowacki, 1992; Lorimar, 1985). The primary sources of fire prior to colonization were Native American activities and lightning strikes (DeVivo, 1990).

The effects of fire on forest soils and vegetation have received extensive study. Two primary edaphic effects of burning include 1) a reduction of organic materials on the forest floor, 2) a short-term increase in fertility (Armson, 1977). Some fire effects on vegetation include 1) a decrease in canopy cover, 2) an increase in herbaceous cover and, 3) an increase in species richness and diversity (Spurr and Barnes, 1980).

The biomass of the herbaceous layer is trivial (< 0.5%) in relation to tree biomass in mature mixed hardwood stands (Whittaker, 1966), yet it is one of the more dynamic components of the eastern deciduous forest (Gilliam and Christensen, 1986). Regeneration and reorganization through competition of the potentially dominant plants of all layers (e.g. overstory, understory, shrub) occurs in the herb layer following fire. Nutrient uptake and productivity are small in the herb layer compared to the overstory, but contributes significantly to food chains for mammals and birds (Siccama et al, 1970). The herbaceous layer acts as a nutrient sink (Muller and Bormann, 1976; Gilliam, 1988; Zak et al, 1980). By absorption during the spring and early summer nutrients are taken-up by the herb layer during the growing season. They are returned to the forest floor by decomposition and resorption of nutrients present in leaves by the perennial (rhizomous) species. Herbaceous plants are consolidated in unincorporated organic matter at the end of the growing season.

The specific role of fire is determined by the resource(s) that are limiting in a particular ecosystem (Gilliam, 1990). Because of this, highly variable changes in the herb layer are expected following a burn. Accordingly, single fire events do not seem to have predictable results on the composition of the resulting herb layer (Van Lear, 1990). Following fire, a mixed hardwood stand in Alabama increased the dominance of red maple (Acer rubrum) while another in West Virginia shifted dominance to oaks (McGee, 1979; Carvell and Maxey, 1969). It has been noted that burns occurring during the winter results in greater herb cover than those areas which are burned during the summer (Gilliam and Christensen, 1986).

The general purpose of this study was to examine the herbaceous layer's response to fire. The factors observed during the course of this study were: 1) fertility changes in areas of varying intensities of fire, 2) response (cover by species) of the herb layer during the 1992 growing season in these areas and 3) evaluation of seedbank potential by comparing greenhouse-grown seedbank samples to the actual regeneration found following wildfire.

Study Area

The study area is located at 82^{0}29'45" West Longitude and 38^{0}13'45" North Latitude within the maturely dissected Kanawha section of the Applachain Plateau physiographic province. The rugged terrain features narrow, steep-walled valleys and high hills. Elevations in the study area ranged from 315 m to 350 m above sea level. Monthly average temperatures range from 2.2^0 C in January to 23.9^0 C in July. The growing season averages approximately six months occurring between mid-April and mid-October. Annual precipitation averages 108 cm and potential evapotranspiration averages 79 cm (United States Corps of Engineers, 1974). The western aspect and the mature overstory provide for the mesic to dry mesic conditions found on the plots. The greatest part of the area is covered with second-growth oak-hickory upland hardwoods.

Soils

Soils found in the unburned and low intensity burned areas are of the Gilpin-Upshur complex. Soils in the moderate and high burned areas are of the Dekalb-Gilpin complex. Both of these soils can be characterized by moderately deep, moderately steep well-drained soils composed of sandstone, siltstone and clay (United States Corps of Engineers, 1974).

Soil samples were taken during early February, 1992 and forwarded to a soil testing laboratory (Table 1). Soil texture analysis was conducted at Marshall University. The laboratory tests were performed so as to conform with "Recommended Soil Testing Procedures for the Northeastern United States" (1991). Soil texture analysis was performed so as to conform with methodology as described by Bouyoucos (1951). These were performed early in the study to determine these characteristics per site so as to better describe each site prior to the first growing season. Due to financial constraints no further laboratory testing was performed during the study.

Woody Vegetation

Canopy cover was determined by the use of a hand-held concave densiometer at each of the 60 sub-plots during May, July and September of 1992. Overstory data was obtained by stretching

Table 1. Soil laboratory fertility results for extractable ions, cation exchange capacity (CEC), and pH. Soil texture results were determined by the hydrometer methods. Two-letter codes represent unburned (UB), low burn (LB), moderate burn (MB) and high burn (HB) plots.

Site	pH	CEC	NO_3^-	NH_4^+	PO_4^{3-}	K^+	Ca^{2+}	Mg^{2+}	Sand	Silt	Clay
			mg/kg						%		
UB	6.4	9.9	12	9.4	3.1	244	1491	230	71	23	6
LB	6.1	10.9	3.3	38	7.8	156	1939	109	56	35	9
MB	5.4	5.7	1	42	6.1	120	853	61	54	36	10
HB	6.7	14.9	21	69	7.4	159	2698	132	81	14	5

a tape 11.3 m from each of the four 0.04 ha plot centers. All understory and overstory trees touched by the tape were tallied. A diameter tape was used at 1.37 m height above the ground on the uphill side of all understory and overstory species to determine diameter at breast height (dbh). Heights were determined using a hand-held clinometer. All nomenclature conforms with Gleason and Cronquist (1991).

Intensity of burn was determined by comparison of 1) degree of understory survival, 2) the height of charcoal on tree stems and 3) relative amounts of forest litter remaining at each site. All sites were located in areas of similar aspect and elevation within a 178.5 ha woodland that was burned by wildfire during mid-November, 1991.

Basal area (BA), importance values and other information on a per hectare basis was calculated for the species comprising the overstory (Tables 2 - 5). Importance values were calculated so as to account for both relative density and relative BA per overstory species.

Yellow-poplar had the highest density (150 stems/ha) at UB plots (Table 2). It also had the highest importance value (77.03) and was the dominant in the overstory at UB. Hackberry and black oak had the lowest density (25 stems/ha) and hackberry had the lowest importance value (2.10). Both were found in the understory.

At LB, dogwood had the highest density (275 stems/ha) (Table 3). Sassafras had the lowest (25). Mockernut hickory had the

Table 2. Overstory species and corresponding density, basal area (BA), height and importance values for the unburned (UB) study area.

Species	Density (stems/ha)	BA (m^2/ha)	Avg.Ht. (m)	Relative Density	Relative BA	Imp. Value
Liriodendron tulipifera	150	13.55	11.6	12.5	64.53	77.03
Cornus florida	375	1.13	2.6	31.3	5.40	36.65
Fagus grandifolia	125	1.96	5.6	10.4	9.34	19.76
Sassafras albidum	100	1.39	5.0	8.3	6.63	14.96
Ulmus rubra	100	1.33	4.6	8.3	6.36	14.69
Acer saccharum	125	0.48	3.1	10.4	2.26	12.68
Cercis canadensis	125	0.06	1.8	10.4	0.29	10.71
Quercus velutina	25	1.07	8.8	2.1	5.03	7.11
Lindera benzoin	50	0.03	1.8	4.7	0.14	4.31
Celtis occidentalis	25	>.01	1.3	2.1	0.02	2.10

Table 3. Overstory species and corresponding density, basal area (BA), height and importance values for the low burned (LB) study area.

Species	Density (stems/ha)	BA (m^2/ha)	Avg.Ht. (m)	Relative Density	Relative BA	Imp. Value
Carya tomentosa	100	8.36	13.2	7.4	37.46	44.87
Cornus florida	275	0.51	2.2	20.4	2.29	22.66
Carya ovata	75	1.28	5.6	5.6	5.72	11.27
Acer saccharum	100	0.23	2.3	7.4	1.05	8.46
Cercis canadensis	100	0.04	1.3	7.4	0.18	7.59
Carpinus caroliniana	50	0.04	2.7	3.7	0.66	3.86

Table 4. Overstory species and corresponding density, basal area (BA), height and importance values for the moderate burn (MB) study area.

Species	Density (stems/ha)	BA (m^2/ha)	Avg.Ht. (m)	Relative Density	Relative BA	Imp. Value
Quercus prinus	225	22.26	12.6	16.1	63.57	79.64
Cornus florida	350	0.33	1.9	25.0	0.94	25.94
Carya tomentosa	175	1.91	4.0	12.5	5.45	17.95
Quercus velutina	125	3.07	3.7	8.9	8.76	17.69
Pinus virginiana	25	4.26	15.9	1.8	12.17	13.96
Acer saccharum	150	0.08	1.4	10.7	0.23	10.94
Quercus alba	25	2.42	13.4	1.8	6.91	8.70
Carya ovata	100	0.39	2.4	7.1	1.11	8.25
Acer rubrum	100	0.06	1.6	7.1	0.18	7.32
Sassafras albidum	75	0.20	2.1	5.4	0.57	5.93
Cercis canadensis	50	0.03	1.6	3.6	0.11	3.68

Table 5. Overstory species and corresponding density, basal area (BA), height and importance values for the high burn (HB) study area.

Species	Density (stems/ha)	BA (m^2/ha)	Avg.Ht. (m)	Relative Density	Relative BA	Imp. Value
Quercus velutina	175	17.13	10.9	17.5	59.40	76.90
Carya tomentosa	175	5.15	7.3	17.5	17.85	35.35
Cornus florida	225	0.55	2.7	22.5	1.89	24.39
Quercus prinus	100	3.71	12.0	10.0	12.86	22.89
Carya ovata	125	1.75	5.0	12.5	6.08	18.58
Cercis canadensis	100	0.06	1.7	10.0	0.23	10.23
Acer saccharum	75	0.48	3.8	7.5	1.66	9.16
Acer rubrum	25	>.01	1.8	2.5	0.03	2.53

highest importance value (44.87), followed by white oak (31.44) and black oak. This suggests an oak-hickory type. Sassafras had the lowest importance value (2.0). The presence of sassafras in the understory suggests succession is still taking place. It may be suggested that the overstory may be reaching climax cover composition, but due to fire-related diebacks still retains some of the intermediate successional species at LB.

Dogwood had the highest density (350 stems/ha) at MB (Table 4) while hackberry had the lowest (25 stems/ha). Chestnut oak had the highest importance value (79.76) and was clearly dominant at MB. Hackberry had the lowest importance value (3.68).

At high burned plots (HB) dogwood had the greatest density (225 stems/ha) (Table 5). Red maple had the lowest density (25 stems/ha) at HB. Black oak had the greatest importance value (76.90) followed by mockernut hickory (35.35) and dogwood (24.39). Chestnut oak followed closely (22.89). This may be another indication of the developing oak-hickory climax cover. Crown dieback was greatest at HB but the oaks and the hickory seems less effected. Red maple had the lowest importance value (2.53).

It has been suggested by Abrams (1992) and Van Lear (1990) that frequent burning of the hardwood forests selects for thick-barked species like oaks. It has been suggested that fire prevention as helped to select for hickories by decreasing fire frequency. No formal records have been kept concerning the frequency of fire on the study area.

Interviews of long-time local residents provided an informal fire and land use history. It was reported that the study area had burned approximately 4 times in the past 20 years. It has been suggested that fire at this frequency may select for oak-hickory cover as found in the burned areas (Van Lear, 1990). It was reported that UB had perhaps experienced fire once in the same time period.

At UB past land use history indicates that it was an active pasture until approximately 1965. This may account for the yellow-poplar dominants found at UB. Fire exclusion may have manipulated species composition in a way which allowed succession to lead to this cover type at UB. The entire study area has been developed for oil and gas production, mostly since 1970. There is little doubt that man's activities has increased the potential for wildfire in the study area. Development, on the other hand, has allowed for the construction of access roads which are well maintained and provide excellent firebreaks. The primary access road was attributed for the exclusion of wildfire onto the UB plots during the fall of 1991.

II. SOIL FERTILITY

Introduction

Changes in fertility levels due to burning have long been of interest. The purpose of this section of this study was to examine fertility changes due to varying intensity of fire on the study area.

One of the primary effects of fire on soil fertility is the production of ash containing many elements, principally phosphorus (PO_4^{3-}), potassium (K^+), calcium (Ca^{++}), and magnesium (Mg^{++}) (Armson, 1977; Wright and Bailey, 1982). The amounts of these elements is dependent upon the type and amount of available fuel and the intensity of the fire. Typically, fire results in increasing these nutrients in a form readily available for use by plants (Armson, 1977). Soil pH is usually raised in soils following fire as a result of ashing of the surface of unincorporated organic material (Fuller, et al, 1955). The higher pH is due to the release of mineral bases in the soluble ash, providing a more suitable environment for free-living N fixing bacteria (Spurr and Barnes, 1980). This has consequences for regeneration since nutrient availability is a important factor in cover reestablishment. The rise in pH associated with additional inputs provided by the deposition of ash provides a reinforcing effect in available nutrients. It has been observed that microbiological activity, particularly bacteria, increases following fire (Fuller, et al, 1955).

Nitrogen is a primary limiting nutrient in most forest soils (Armson, 1977). Although many forms of nitrogen exist, only the ammonium form (NH_4^+) and the nitrate form (NO_3^-) are of use to higher plants. Studies of fire effects on N have had widely different results. Knight's (1966) study of available N in a forest soils in the coastal Douglas-fir (<u>Pseudotsuga</u>) showed a positive correlation between heat of the burn and the net loss of N in forest soils. Christensen (1977) found no significant increases of N following a burn in the coastal plains of North Carolina. A preliminary increase in N was found during the short-term in the soils of Christensen's (1977) study but declined rapidly after the start of the next growing season. This was attributed to the rapid uptake of N by the fast-growing herbaceous layer. In all cases there is a long-term net loss of N. This is attributed to the volatilized N lost to the atmosphere during the fire, as well as the loss by overland flow and sub-surface N leaching following the fire (Spurr and Barnes, 1980).

Methods and Materials

Soil samples were taken from the top 5 cm of each 90° section of each site and homogenized to represent each plot. The soils were taken to Marshall University's greenhouse where they were separated from the organic matter, passed through a #10 soil sieve (2 mm mesh) and dried on kraft paper. After drying,the soils were evaluated in a fertility bioassay.

A fertility bioassay was performed using *Poa pratensis* L. (Kentucky Bluegrass) as the indicator species. Seed was purchased locally at an agricultural co-op outlet. The prepared soils were placed in 28 pots, bluegrass seed planted, and were amended with fertility treatments providing full and partial inputs. Treatments were applied to the homogenized soils from each study plot (UB, LB, etc.) as follows:

Pot #1	Pot #2	Pot #3	Pot #4	Pot #5	Pot #6	Pot #7
H_2O	Full	-N	-P	-K	-Mg	-Ca

Hoagland's solution was prepared on March 24, 1992 and was stored in a cool, dry, darkened area throughout the course of the experiment. Application rates were 20 ml/week for four weeks for each pot.

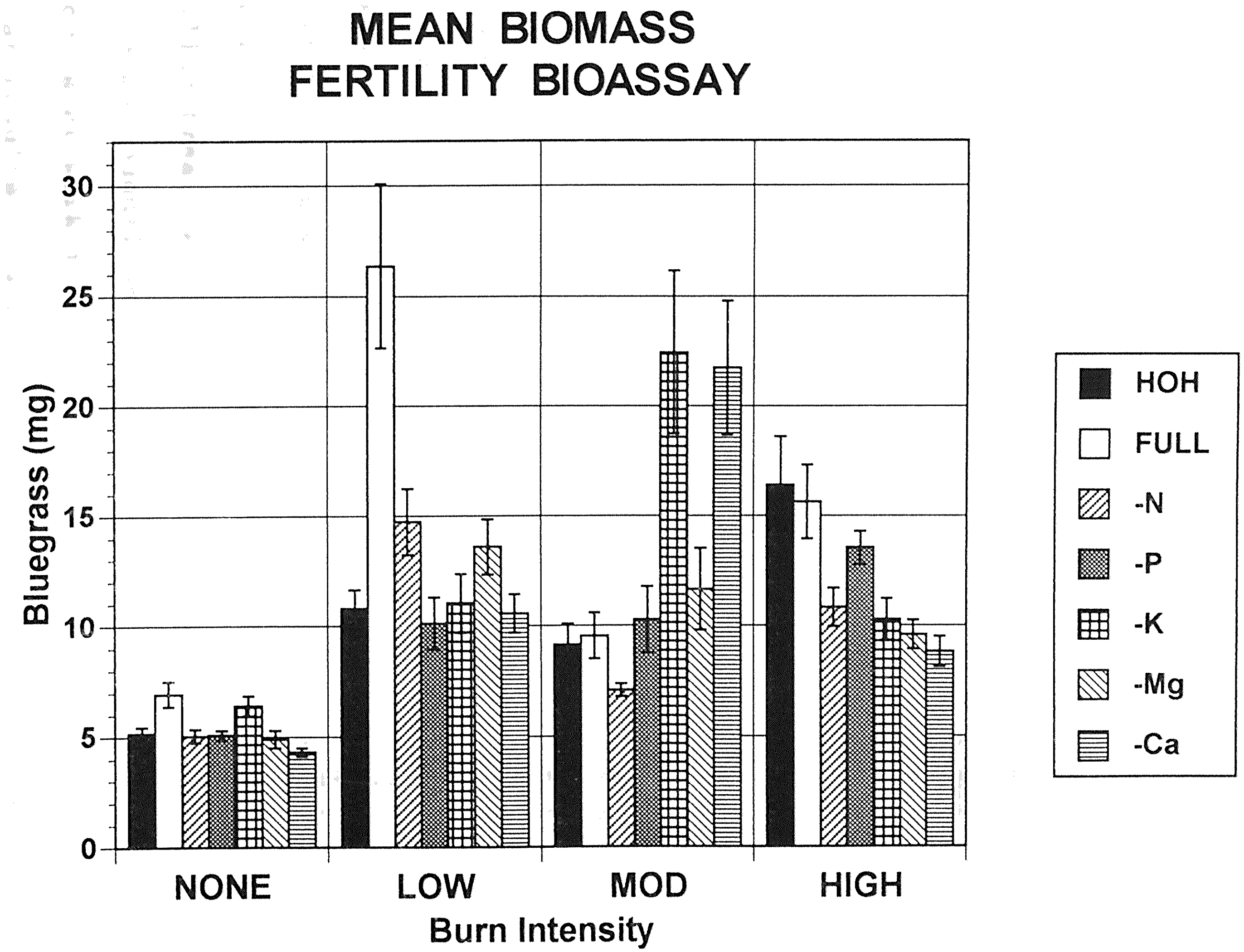
To provide a more equal comparison of biomass production between pots all of the bluegrass stems were cut at the soil level on April 20 and were placed back into the greenhouse. This was an effort to increase accuracy by allowing for biomass production from fully developed root systems. All were watered as required using glass-distilled water during the course of the experiment.

On June 7, the bluegrass was unpotted, cut at the soil surface and placed in individual kraft paper bags for drying. The bags were placed in an oven and dried at 40.5^0 C for a minimum of 1 week prior to weighing. Individual stems were weighed with a analytical balance.

By comparing the resulting bluegrass's biomass, the fertility differences existing between the soils were examined. The data obtained was put in spreadsheet form and analyzed using SAS statistical procedures (Proc SORT and Proc MEANS, 1985) on Marshall University's mainframe computer system. Duncan's multiple range test was performed to determine any significant fertility differences between soils.

In the soils from the UB, no significant differences were found with the exception of full fertility treatment and treatment -K (Figure 1). The lowest mean biomass (4.29 mg) in the experiment was found in the unburned soils. Although full treatment produced the highest biomass in UB soils (6.92 mg), the significant relationship with -K implies that UB soils are not limited by any individual or combination of nutrient(s). These results may indicate a general low fertility level. UB soils have the lowest mean biomass production of all soils assayed (5.41 mg). Overall, the nutrients are most likely tied up in the nutrient cycle. The low overall levels of availability may limit high nutrient demanding species establishment on unburned sites.

Figure 1. Fertility experiment results. Indicator's (bluegrass) mean biomass per sample plot per fertility treatment. Biomass is expressed in milligrams.


MEAN BIOMASS
FERTILITY BIOASSAY
Bluegrass (mg)
0
5
10
15
20
25
30
NONE
LOW
MOD
HIGH
Burn Intensity
HOH
FULL
-N
-P
-K
-Mg
-Ca

Results and Discussion

At LB, no significant differences were found in the biomass of those plants which received water only and those which received treatment -P, -K,-Mg, and -Ca (Figure 1). LB appears to be much like UB in that no single nutrient appears to be limiting for growth. Although no significant differences were found between Mg, P, K and Ca, the mean biomass was higher for -Mg than the others (13.57 mg). No significant differences were found between the -N and -Mg treatments. This suggests that the soils at LB are not limited primarily by Nitrogen. A synergistic effect was observed in the pot which received the full fertility treatment producing the highest mean biomass found in the fertility experiment (26.35 mg). A combination of all nutrients produced more biomass than the omission of any individual component. This implies that the soils at LB are not limited by any single nutrient. LB soils produced the highest overall mean biomass of all soils tested (13.88 mg).

At MB, no significant differences were found in the pot which received water only and that which received the full fertility treatment. The high biomass found in the -K and -Ca pots seems unusual because of this. This suggests that some other factor is at work in these pots. Christensen (1977) reported similar results in a fertility experiment using burned forest soils and suggested that "other factors" were responsible for these results. It may be that free-living microbial actions caused this by making available nutrient in a form available for plant use. Changes in populations of soil bacteria, actinomycetes and fungi are greatest in the upper 2 to 5 cm following fire (Spurr and Barnes, 1980). Clostridium and Azotobacter are free-living N-fixing bacteria common in most forest soils (Armson, 1977) and may responsible for these results. The lowest biomass in MB soils was found in the -N treatment. This suggests that N is the greatest limiting nutrient in MB soils.

Although the greatest mean biomass was found in the group which received water only in HB soils, no significant differences were found between water only, full fertility treatment and treatment -P (Figure 1). No significant differences were found between the remaining treatments. This infers that the maximum amount of nutrients are available for plant use in HB soils and the lack of any one or the combination of all is not limiting growth. HB had the lowest mean biomass of the burned areas (12.15 mg) but even the lowest biomass found was significantly greater than the highest biomass found in UB soils. Soil texture analysis results show HB soil to have the highest sand component of all soils tested (Table 1). Sandy soils are known to have lower cation exchange capacities (CEC) (Armson, 1977). This may be limiting biomass production in this experiment.

Duncan's multiple range test again was used to determine overall differences between sites. MB and HB soils were least different. Soils at UB and LB plots were significantly different than at MB and HB. Soils at MB and HB were significantly different compared to each other. Though the CEC may be limiting at HB, the lack of response to nutrient applications suggests that fertility may not be limiting growth on those sample plots. LB soils treated with water only produced a significantly higher mean biomass than that of MB soils.

No single nutrient was limiting in MB soils. This suggests that while potential fertility at LB is less than in HB soils, fertility should not be as limiting as in MB soils which are limited by N availability. Soils on UB sample plots yielded the lowest biomass and may be limiting for herbaceous establishment and production. While specific interpretations of potentially limiting nutrients are difficult to make, general patterns suggest that fire increases fertility in burned soils. This appears largely related to increases in available N.

III. SEEDBANK STUDY

Introduction

The purpose for this section was to compare consolidated forest floor sections grown under controlled conditions to the resulting herbaceous layer following the varying intensities of wildfire. This would assist in understanding how the fire influenced the remaining seedbank as well as determine the similarities of the resulting herbaceous cover.

It has been suggested that the major evolutionary force determining the nature of the seedbank is the selective advantage derived from the mechanisms of seed dormancy and germination which allow seedlings to evade the potentially dominating effects of established plants (Thompson and Grime, 1979). To a large part, it is these same mechanisms which provide for the regeneration of the herbaceous layer following burning. Although fire stimulates seed germination, seed in the forest litter may be destroyed (Ingersol and Wilson, 1990). Multiple burns in a short period of time has resulted in a dramatic reduction of seed (Schiffman and Johnson, 1992). Seasonal variations of seedbank expression have been noted as well (Thompson and Grime, 1979). It has been suggested that succession following fire is dependent upon vegetative reproduction and post-disturbance seed dispersal (Schiffman and Johnson, 1992).

Methods and Materials

Consolidated seedbank samples were taken during the first week of March, 1992. A "soil-rinsed" axe was used for cutting two forest floor samples from each 90^{0} section of all plots. Using a square-edged shovel the consolidated seedbank samples were loaded into the plastic flats (60 cm by 30 cm by 5 cm). The bottom of the flats were lined with leaves to prevent soil loss from the erosive actions of watering. The 16 flats were then transported to Marshall University's greenhouse. The seedbank samples were watered as required using glass-distilled water until late July, when tap water was substituted for the last 3 weeks of the experiment. Plants were identified to genus and species (when possible) during mid-May and mid-August. This was accomplished to examine the potential response of the seedbank following fire. All nomenclature follows Gleason and Cronquist (1991).

Results and Discussion

The phenology of the greenhouse plants was advanced to the point where only in May (vernal species) and July (estival and serotinal species) identifications were made of the resulting growth (Appendix I). There were no prevernal or autumnal species found. Through the course of this study 67 species found in 58 genera representing 30 families were identified. Overall species richness was 34, 33, 31 and 29 for HB, LB, UB and MB sites respectively. Growth occurred in all samples except in one of the four taken at MB. This sample was barren in the May identifications.

According to Core (1966), most vernal species pass a long dormant period buried in the ground in rhizomous, crom, tuber or bulb form. Examples which were present during the May identifications were Dentaria laciniata (cut-leaf toothwort), Oxalis stricta (upright yellow wood sorrel), Viola papilionacea (common blue violet) and Polygonatum biflorum (common soloman's seal). Many estival species have been introduced from Europe or have immigrated from the prairies which lie to the west (Core, 1966). Lilies, roses, legumes, umbellifers, milkweeds, borages, mints and figworts bloom during this period. Many grasses bloom early in the estival season (Core, 1966). Examples which were present during the August sampling were Desmodium sp. (sticktights), Lespedeza sp. (lespedeza) and Rosa carolina (pasture rose). This group exhibited the greatest variance in phenology during the course of the study. Most estival species are shade-intolerant and are typically found in open places rather than in the forest floor shaded by the canopy (Core, 1966). The presence of these species in part may be attributed to the greenhouse environment. No shading of the samples occurred and soil moisture conditions were well-maintained. These conditions would select for these plants during the experiment and would provide for a lowering of environmental resistance possibly allowing for development at a more rapid rate. This may suggest an explanation to the advanced phenology of the greenhouse-grown samples over the herb layer as observed on the study plots.

IV. HERBACEOUS LAYER

Introduction

As previously discussed, the herbaceous layer performs various important functions following wildfire. A few would include: 1) the reduction of the erosion potential of the site, 2) acts as a nutrient sink for the site, 3) provides for the reorganization of species composition by selection for those species more tolerant to fire. The purpose of this section of the study was to observe the response (cover by species) of the herbaceous layer during the 1992 growing season in the areas of varying intensities of burn. Species richness and diversity, canonical discriminent analysis and canopy influence were observed and compared between each site.

Methods and Materials

A circular 0.04 ha (11.3 m radius) plot was established in each area designated as UB, LB, MB and HB in early February, 1992. Three sample plot centers were established within each plot using stratified random placement. Five sub-plots (1 m^2) were located around each sub-plot center at 0^0, 72^0, 144^0, 216^0 and 288^0. The distance of each sub-plot from the sample plot center was predetermined so the samples would be equally representative of the interior as well as the exterior of each sub-plot (Gaiser, 1951).

Herbaceous cover by species was determined at each of the 60 sample plots by the use of a circular 1 m^2 hoop during May, July and September of 1992. Using these sampling times vernal, estival and serotinal plants were accounted for. No destructive harvest of any plants found on the sample plots was performed during the course of study. If removal of a plant was required for identification, one was located outside the sample plot and taken. All nomenclature conforms with Gleason and Cronquist (1991).

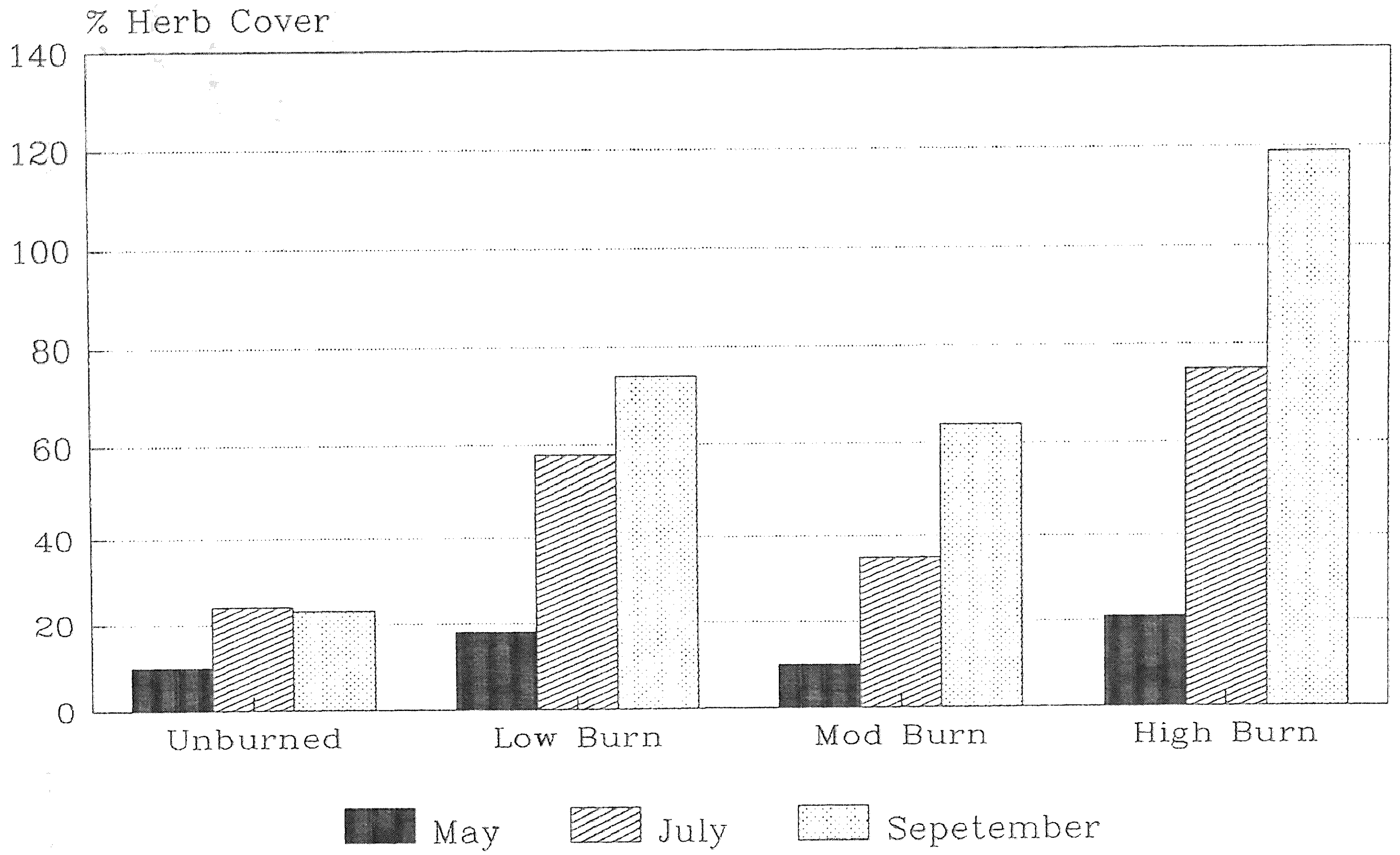
Results and Discussion

A total of 98 species found in 79 genera representing 44 families were identified in the herbaceous layer on the sample plots during the course of this study (APPENDIX II). The greatest cover occurred in September on HB (119%) (Figure 2). The lowest cover occurred in May at UB and MB (10%). The greatest change in cover (98%) was at HB and the least at UB (14%). At UB, cover was greatest during July (24%). All burned plots increased in cover over the course of this study.

Lindera benzoin (spicebush) comprised the greatest relative cover at UB in May (43.7%), followed by immatures (27%) and Parthenocencis quinquifolia (virginia creeper) (8.3%). In July spicebush continued to comprise the greatest relative cover

Figure 2. Mean percent herbaceous cover per plot during May, July and September, 1992.

HERBACEOUS COVER



(28.5%) followed by Verbena urticifolia (nettleleaf vervain) (29%) and Cornus florida (dogwood) at 15%. In September spicebush increased to 30% followed by nettleleaf vervain (18%) and dogwood at 15%. This poses an interesting dichotomy for spicebush is typically found in areas of relatively high fertility and is known as an indicator of good site quality. Nettleleaf vervain is an indicator of poor soil conditions, commonly found in waste areas. Spicebush, being a woody species can add onto previous years of growth each growing season. This would provide for relatively stable or slightly increased amounts of cover until maturity. Nettleleaf vervain is herbaceous and is known to compete well with other plants in thickets (Strausbaugh and Core, 1977). This is an indication of at least a degree of shade tolerance. The poor fertility of the soil may favor its establishment. The aspect, low fertility availability, and the sandy clay loam of the soil may interact to provide marginal conditions allowing for the resulting cover of both species.

At LB during May, immatures had the greatest relative cover (45.7%) followed by Vaccinium vacillans (late low blueberry) (9.5%) and Panicum clandestinum (panicum) (9%). During July late low blueberry was highest with 31.3% relative cover, followed by Sassafras albidum (sassafras) (26.7%) and Polygonatum biflorum (common solomon's seal) (26.3%). In September sassafras increased to 37.3% relative cover followed by Desmodium canadense (sticktight) at 36% and Rubus spp. (raspberry/blackberry) with 30%. All of the species which occurred in abundance on LB were known colonizers of areas following disturbance (Strausbaugh and Core, 1977). The increase in nutrient availability due to burning, aspect, and sandy clay texture of the soil acted to provide for the second highest cover (74%) found on the study area. Sassafras, comprising the greatest woody cover in the herbaceous layer on LB, was coppice in origin. The remainder of the cover was herbaceous.

Immatures comprised the largest relative cover at MB during May (17.3%), followed by late low blueberry (5.7%) and <u>Viola papilionacea</u> (common blue violet) (4.7%). During July sassafras was greatest (29.7%), followed by <u>Panicum</u> <u>dichotomum</u> (bushy panic grass), common blue violet (13.7%) and <u>Panicum</u> <u>clandestinum</u> (deertongue grass) (10.3%). In September sassafras had the greatest cover (39.3%) followed by deertongue grass (35.3%) and bushy panic grass (23.3%). Sassafras was again coppice in origin. and was the only woody species which comprised major cover at MB. Panicum cover was significant at LB. This implies the importance of grasses following disturbance. The relatively low nutrient demand of these plants renders them as minor competitors for other herbaceous species establishment at MB. They also provide for soil stabilization thereby retaining the remnants of valuable topsoil making more nutrient available for the recovering herbaceous layer. Fertility was lowest at any of the burned areas at LB but were still significantly higher than UB soils. The sandy clay texture of MB soils were very similar in other regards to LB.

At HB during May immatures had the greatest relative cover (32.7%) followed by Cercis canadensis (redbud) (8.6%) and Smilax rotundifolia (common greenbrier) (8%). In July Phytolacca americana (polkweed) had the greatest relative cover (96.7%) followed by Vitis spp. (wild grapevine) (22.3%) and common blue violet (21.7%). Polkweed had the greatest relative cover in September (100%) followed by Carex willdenowii (sedge) (63.3%) and Rubus spp. (raspberry/blackberry) (50%). The soils on HB had the second highest fertility found in the experiment. In the fertility experiment soils were found not to be limited by available nutrient. The loamy sand texture of the soils in concert with on-site fertility factors provided for the establishment of the lush herbaceous cover. Because C. willdenowii (sedge) represented a major cover species during the September field observation the importance of grasses to the recovery of a burned site is reemphasized. The high sand component of soil textures did not limit the CEC of these soils to the point that they could not provide for the subsequent recovery of the herbaceous layer.

When considering overall mean herbaceous cover (Figure 2) HB was greatest throughout the study (72%). LB had the second greatest cover at any time during the study (50%). Of the burned areas MB had the lowest mean cover of any during the course of the study (36%). All burned areas increased in herbaceous cover during the study season. At UB cover was greatest during July (24%). This is contrary to the trend displayed in the burned areas. The low level of fertility in UB soils coupled with the low availability of light probably interacted to cause this situation. *Allium* sp. (wild onion), *Arisaema triphyllum* (jack-in-the pulpit), *Asimina triloba* (pawpaw), *Botrychium virginianum* (rattlesnake fern), *Caulophyllum thalictroides* (blue cohosh), *Celtis occidentalis* (hackberry), *Dicentra cucullaria* (dutchman's breeches), *Duchesnea indica* (indian strawberry), *Podophyllum peltatum* (may-apple), *Prenanthes serpentaria* (rattlesnake root), *Prunus serotina* (wild black cherry), *Thalictrum dioicum* (early meadowrue), and *Ulmus rubra* (red elm) were found exclusively at UB.

Antennaria plantaginifolia (field pussytoes), *Digitaria sanginalis* (crabgrass), *Erigeron strigosus* (daisy fleabane), *Houstonia longifolia* (long-leafed summer bluets), *Polygonatum biflorum* (common solomon's seal), *Quercus alba* (white oak), and *Uvularia sessilifolia* (sessile-leaved bellwort) were found only at LB.

Gnaphalium obtusifolium (cudweed), *Plantago virginica* (dwarf plantain) and *Polygonum persicaria* (lady's thumb) were exclusive to MB. *Ailanthus altissima* (tree-of-heaven), *Panicum gattingeri* (tickle-grass), *Panicum* sp. (panicum), *Polygala verticillata* (whorled milkwort), *Scutellaria incana* (downy skullcap) and *Trifolium pratense* (red clover) were found only at HB.

The fidelity of these plants to a single site is probably due to a number of factors. Rhizomatous regeneration by some of these species is responsible for their appearance and will be discussed in the seedbank section of this Study. Seed in the remaining unburned organic material may account for the appearance of some species while wind and animal dispersion may account for the remainder of the site-exclusive regeneration. It should be noted that UB contained most of these species. This may possibly be an indication of the composition of the "steady state" forest's herbaceous layer (Spurr and Barnes, 1980). On the burned sites several woody species were found in the herbaceous layer. This is not the case at UB where only a few woody species were found in the herbaceous layer (APPENDIX II). It also may indicate that these are plants with narrow ecological tolerance. This would approach an explanation to their seemingly specific distribution.

The species which were ubiquitous may possibly be exhibiting the widest range of ecological tolerance. Many of these species are known for occurring over many different type sites. *Acer rubrum* (red maple), *Carex* sp. (sedge), *Carya ovata* (shagbark hickory), *Carya tomentosa* (mockernut hickory), *Cercis canadencis* (redbud), *Cornus florida* (dogwood), *Galium lanceolatum* (lanceleaf wild liquorice), *Geum virginianum* (virginia avens), *Liriodendron tulipifera* (yellow poplar), *Lonicera japonica* (japanese honeysuckle), *Parthenocissus quinquefolia* (virginia creeper), *Quercus velutina* (black oak), *Rubus* spp. (blackberry/raspberry), *Sassafras albidum* (sassafras), *Smilax rotundafolia* (common greenbrier), *Verbena urticifolia* (nettleleaf vervain), *Viola papilionacea* (common blue violet) and *Vitis* spp. (wild grapevine) were found at every plot.

Many species were found in at least two of the burned areas and not at UB. These species ranged from early colonizers following disturbance to those found in rich woods (Strausbaugh and Core, 1977). These species represent the greatest numbers found during the course of this study. These findings follow Gilliam (1991) who found that the greatest species richness occurred following fire in an oligotrophic coastal plain forest. Those found in this study were *Andropogon virginicus* (broomsedge), *Antennaria plantaginifolia* (pussytoes), *Arthraxon hispidus* (no common name), *Aster infirmus* (white aster), *Carex pensylvanica* (sedge), *Carex willdenowii* (sedge), *Cassia nictitans* (wild sensitive plant), *Chimaphila maculata* (spotted wintergreen), *Coreopsis major* (wood tickseed), *Corydalis flavula* (yellow corydalis), *Desmodium canadense* (sticktight), *Epilobium angustifolium* (fireweed), *Erechtites hieracifolia* (fireweed), *Eupatorium serotinum* (late-flowering thoroughwort), *Fragaria virginiana* (virginia strawberry), *Galium circaezans* (wild liquorice), *Gallinia stipulata* (no common name), *Hedeoma pulegioides* (american penny royal), *Heuchera americana* (alumroot), *Hieracium* sp. (hawkweed), *Lespedeza cuneata* (lespedeza), *Lespedeza intermedia* (lespedeza), *Morus rubra* (red mulberry), *Oxalis stricta* (upright yellow wood sorrel), *Panicum clandestinum* (deertongue grass), *Panicum dichotomum* (bushy panic grass), *Phytolacca americana* (polkweed), *Pinus virginiana* (virginia pine), *Poa* sp. (bluegrass), *Quercus prinus*, (chestnut oak), Rhus copallina (winged sumac), Rhus glabra (smooth sumac), Rhus radicans (poison ivy), Rhus typhina (staghorn sumac), Robina pseudo-acacia (black locust), Rosa carolina (pasture rose), Saxifraga virginiensis (early saxifrage), Sedum ternatum (wild stonecrop), Senecio obovatus (squaw-weed), Senecio sp. (squaw-weeds/ragworts), Solidago rugosa (wrinkled-leaf goldenrod), Specularia perfoliata (venus' looking glass), Vaccinium vacillans (late low blueberry), Viburnum acerifolium (maple-leaf arrowwood) and Viola pensylvanica (smooth yellow violet).

Seedbank Samples

Of the 67 species which occurred in the greenhouse samples 13 (19.4%) were not found in the herb layer of the study area (Table 6). The majority of these species were found only in one sample or appeared only once during the study period. This was not the case for Potentilla simplex (common cinquefoil) or Cunila origanoides (dittany). Both are commonly found in open areas. With the decrease in canopy cover in the burned areas these plants may have been limited in the study plots by sunlight availability. This suggests that seedbank potential is greater than that which was expressed in the herbaceous layer. These findings are consistent with Schiffman and Carter (1992) who also suggest that past land use practices may have a bearing on seedbank expression.

Table 6. Species identified in the seedbank samples which were not represented in the herbaceous layer.

Species	Common	Occurance	Comments
Acalypha rhomboidea Raf.	Common 3-seeded mercury	UB	Dry fields, woods and thickets
Aster prenantheoides Muhl.	Crooked stem aster	UB	Woods, low places
Cunila origanoides (L.) Britton	Dittany	LB,MB,HB	Dry woods open banks
Danthonia spicata (L.) Beauv.	Poverty grass	MB	Dry, poor soils
Dentaria lanciniata Muhl.	Cutleaf toothwort	UB	Rich, moist woods
Fagus grandifolia Ehrh.	American beech	LB	Common, rich soils
Helianthus microcephalus T.& G.	Small-headed sunflower	LB	Moist soils
Hypericum mutilum L.	Small-flowered St. John's-wort	UB	Low areas
Lactuca sp.	Wild lettuce	UB	Open places
Lobelia inflata L.	Indian tobacco	UB	Open fields
Monarda sp.	Bergamot\balms	LB	Rich woods
Polygala sanguinea L.	Rose polygala	HB	Acid fields
Potentilla simplex Michx.	Common cinquefoil	LB,MB,HB	Dry, sandy, poor soils

Another factor in altering seedbank expression may be fire. This did not seem to be the case in this study. Almost all of the species found at UB samples were present in samples from burned areas. These were _A. saccharum_ (sugar maple), _D. laciniata_ (cut leaf toothwort), _G. lanceolatum_ (lanceleaf wild liquorice), _H. mutilum_ (small-flowered St. John's-wort) and _U. rubra_ (red/slippery elm).

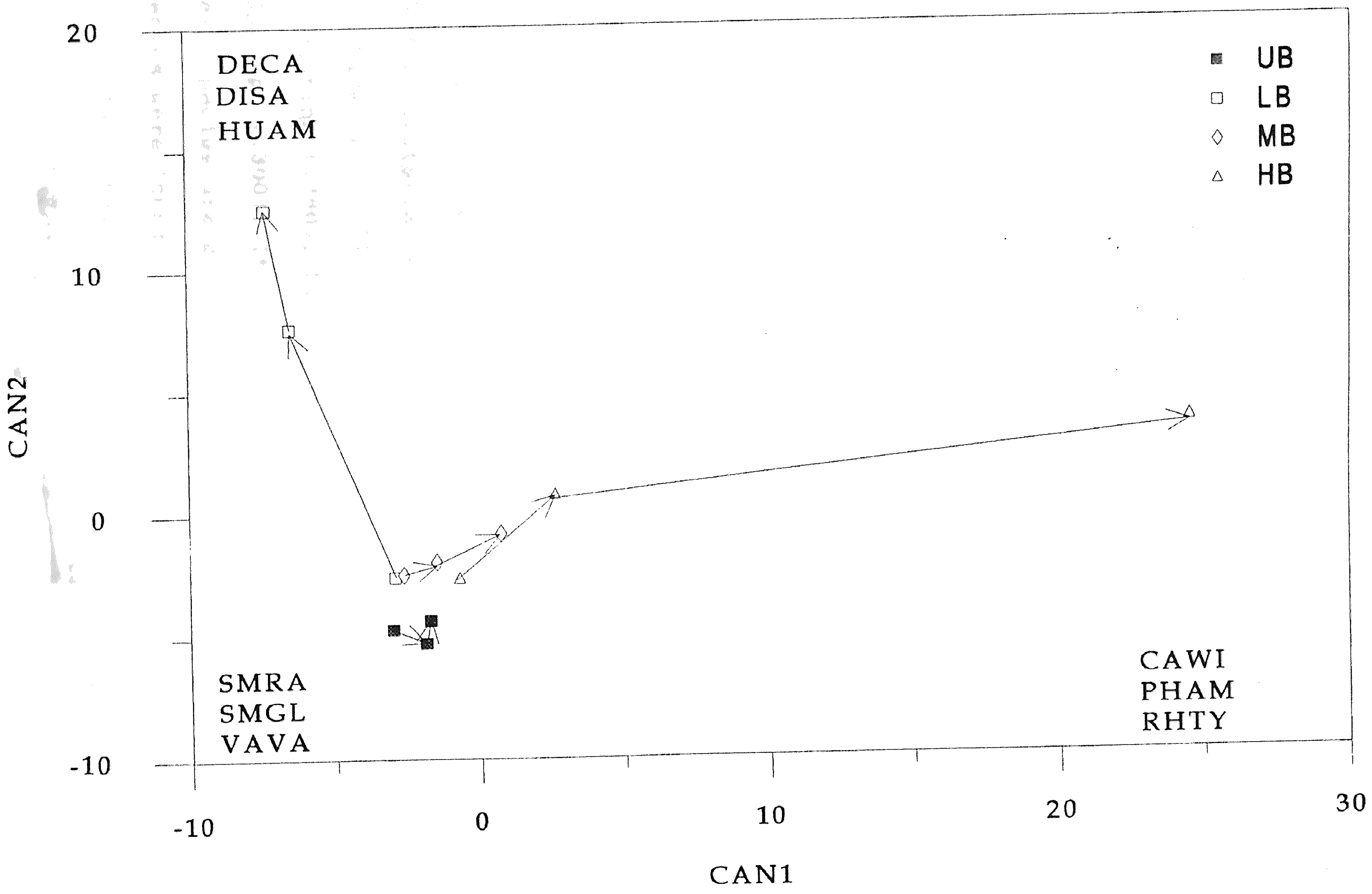
Thompson and Grime (1979) suggest that seasonal influences of seed production provide for variation of seedbank species composition and may be responsible for the varying degrees of similarity. The greenhouse-grown samples should not have been influenced to a large degree by the variability of seasonal influences.

It should be noted that the vast majority (80.6%) of the species found in the seedbank experiment were well-represented in the actual herbaceous layer. Samples from each plot were fairly representative of the herbaceous layer found in the immediate area of the sample (UB_{sample}-UB_{plot}, LB_{sample}-LB_{plot}, etc.).

Canonical Discriminant Analysis

Canonical discriminant analysis was used in determining how cover at each plot changed due to the occurance of new species relative to each other during the growing season (Figure 3). This provides a relative comparison of the herbaceous layer as found

Figure 3. Canonical discriminant results. Plots are marked to designate sub-plot samples during May, July and September, 1992. Species which influenced the greatest change due to their cover across the gradient were (4 letter codes) CAWI (Carex willdenowii), PHAM (Phytolacca americana), RHTY (Rhus typhina), DECA (Desmodium canadense), DISA (Digitaria sanguinalis), HUAM (Heuchera americana), SMRA (Smilacina racemosa), SMGL (Smilax glauca) and VAVA (Vaccinium vacillans).


20
10
0
-10
CAN2
-10
0
10
20
30
CAN1
DECA
DISA
HUAM
SMRA
SMGL
VAVA
CAWI
PHAM
RHTY
■ UB
□ LB
◇ MB
△ HB

at each of the plots through the first growing season following burning. UB showed the least change followed by MB. The greatest herbaceous cover was found at any time during this study occurred at HB and LB at any time during the first growing season following the fire. This may be due to the fertility, CEC, overstory cover and seedbank potentials at each plot and their interactions. The manner in which each plot changed during the growing season relative to the others was determined by the total canonical structure. This use allowed for a comparisons between plots by comparison of each species' frequency and cover amounts.

The species and order of importance most instrumental to the differences between plots along the CAN1 axis were C. willdenowii (0.728), P. americana (.548), R. typhina (.538), S. incana (.450), Vitis spp. (.450), R. glabra (.443), A. infirmus (.441), A. virginicus (.434), L. tulipifera (.394) and V. papilionacea (.392).

The species and order of importance most instrumental to the differences between plots along the CAN2 axis were D. canadense (.549), Digitaria sanguinalis (.546), H. americana (.513), Epilobium sp. (.511), V. acerifolium (.428), V. vacillans (.394), Q. velutina (.360), L. intermedia (.327), R. carolina (.305) and Vitis sp. (.300). It is of interest that the greatest number of these species are grasses and herbaceous plants. Only two tree species were found to be important when using canonical discriminant analysis.

Herbaceous Species Richness and Diversity

Species richness and diversity for each plot was calculated from cover data obtained by field observations for May, July and September. Canonical discriminant analysis was used to determine how cover changed on the different plots during the first growing season following to wildfire due to the addition of new species. Those species most important to that change were determined using the same technique.

The greatest species richness occurred during September at LB and HB (57) (Figure 4). MB diversity was nearly identical (56). At UB richness remained the same throughout the study period (30). Richness increased at constant rate through time at MB and HB. MB had 25 taxa present during May. In July this increased to 40 and reached 56 during September. HB was nearly identical with 26 during May, 42 during July and 57 in September. Richness at LB increased from 29 in May to 52 in July and 56 in September. The May to July period showed the greatest increase in richness found during the study.

Species diversity (Shannon-Wiener) closely followed the pattern established by species richness (Figure 5). This suggests that the addition of new taxa was more important to the resulting index number than their equitability on the burned plots. Diversity at UB did not follow this pattern. Diversity during July was greatest (1.23) followed by September (1.19) and May (1.10). This suggests that although richness remained constant at

Figure 4. Species richness per plot during May, July and September, 1992.

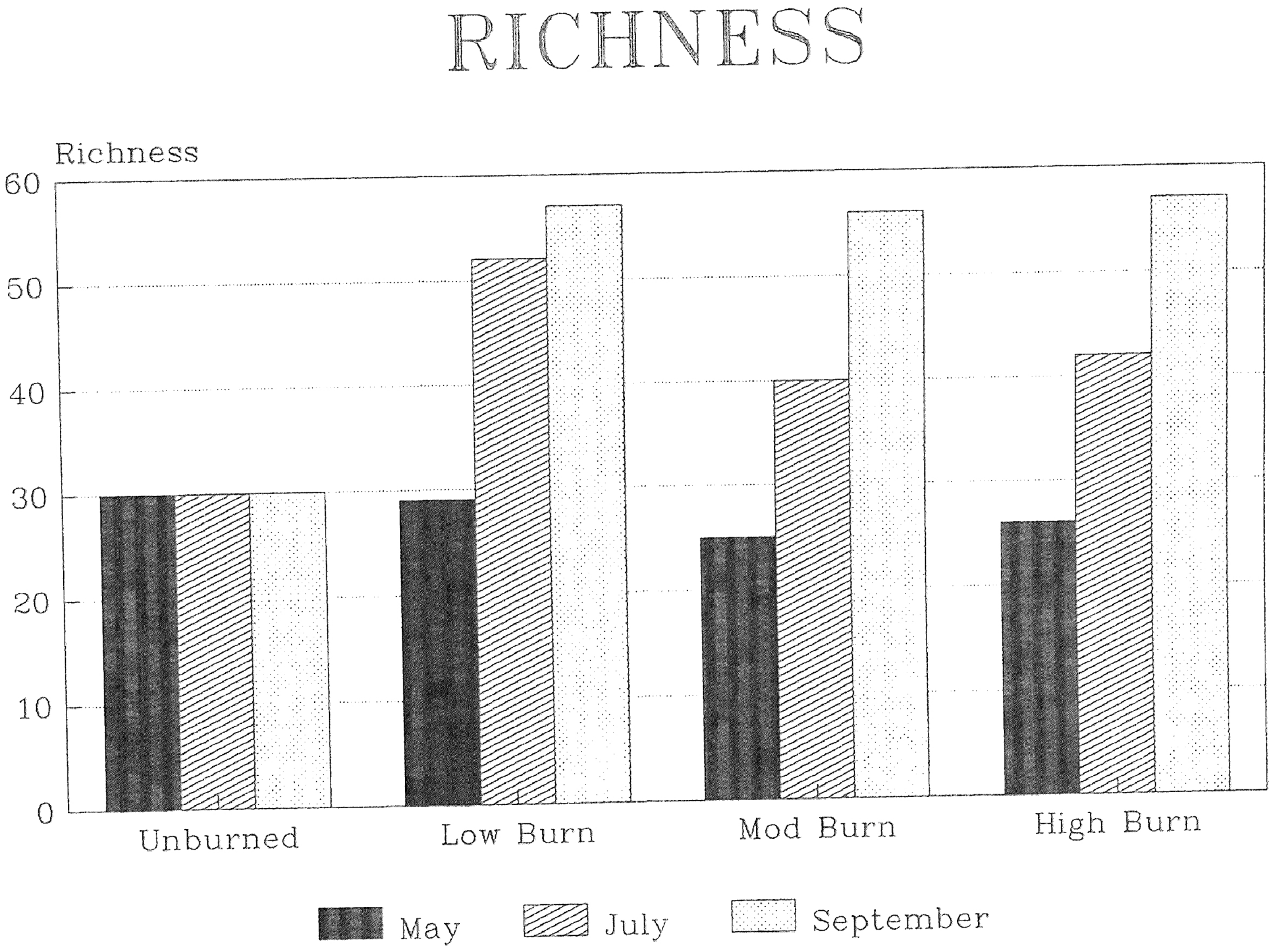
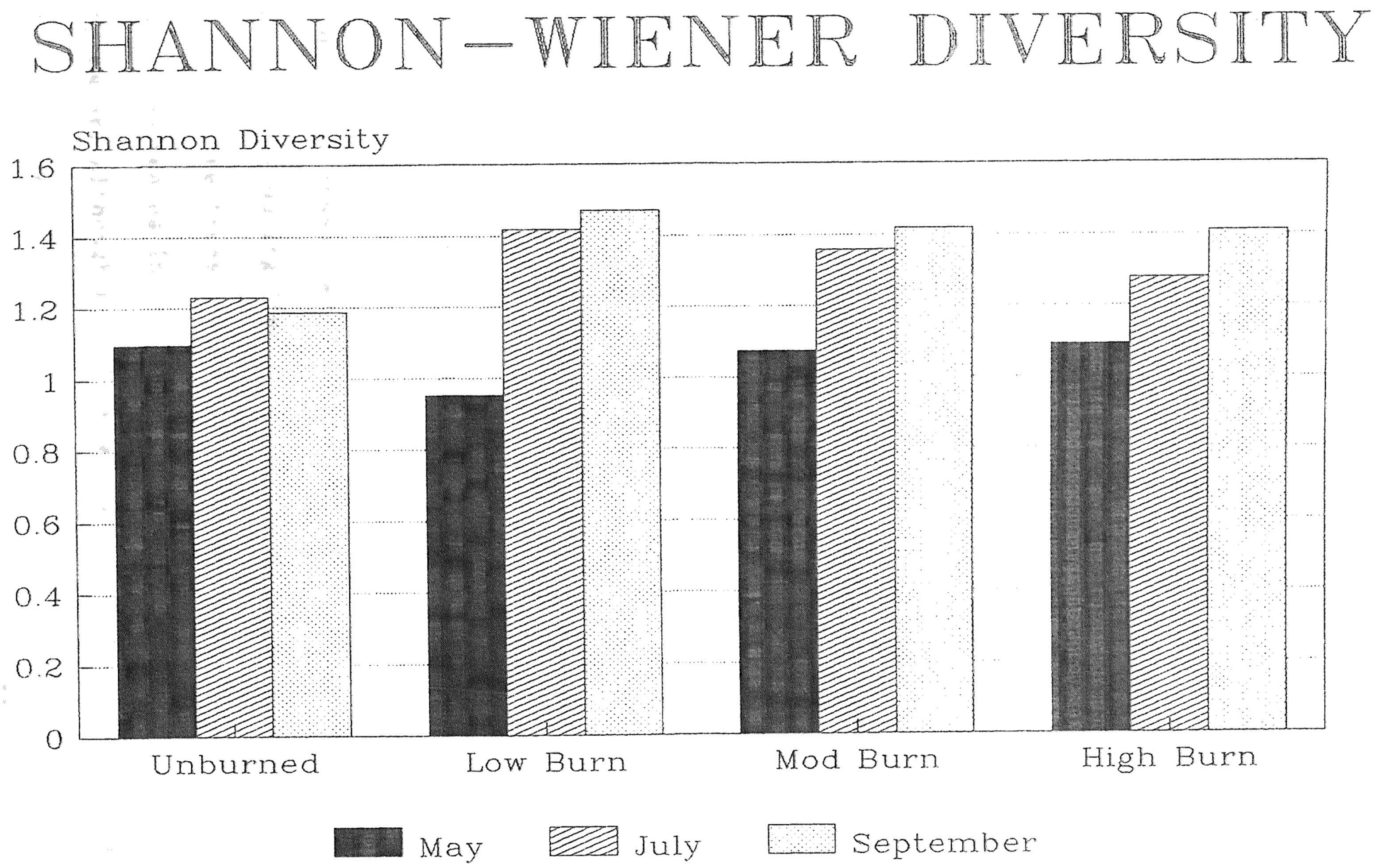

RICHNESS
Richness
60
50
40
30
20
10
0
Unburned
Low Burn
Mod Burn
High Burn
May
July
September

Figure 5. Shannon-Wiener species diversity values for each plot during May, July and September, 1992.


SHANNON–WIENER DIVERSITY
Shannon Diversity
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Unburned
Low Burn
Mod Burn
High Burn
May
July
September

UB, the replacement of the early cover by late-season herbs may be reflected in the resulting diversity. The relatively high fertility may have played a role in the increase in species diversity at LB from May through July.

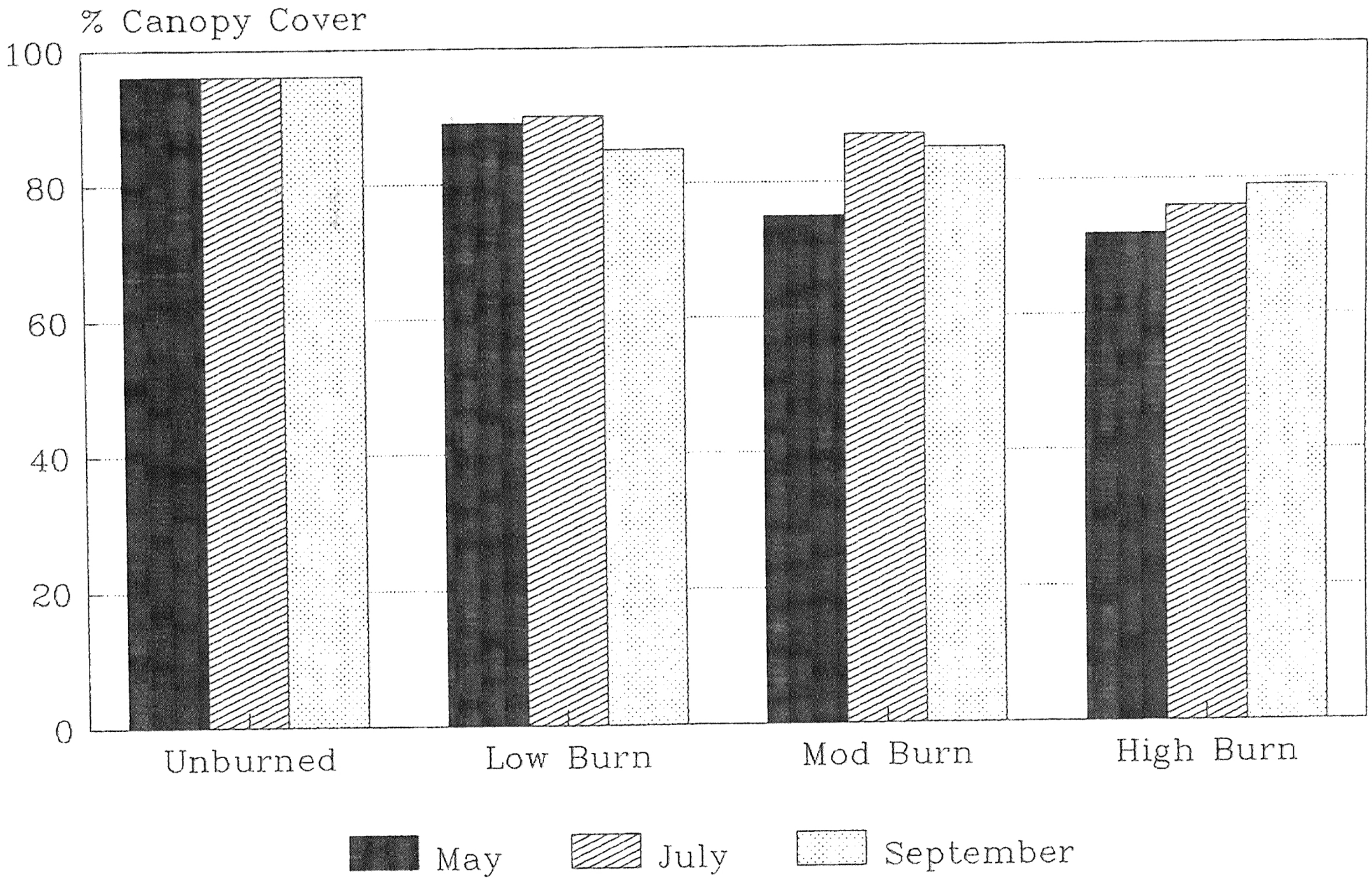
Canopy Cover

Canopy cover remained constant throughout the growing season (96%) at UB (Figure 6). Canopy cover at LB was highest during July (90%) followed by May (89%) and September (85%). At MB cover was highest during July (87%) followed by September (85%) and May (75%). Canopy cover was highest during September (79%), followed by July (76%) and May (21%).

The trends at MB and LB were similar with greatest cover occurring during July. May was a different case with the greatest cover at LB of all the burned areas. This may be due to the intensity of the burn. Although the shrub layer (1-3m) was sparse at LB, it was nonexistent at MB and HB and added nothing to the densiometer measurements. Mortality of overstory trees occurred at all plots during the course of the first growing season. In all cases the trees leafed-out prior to dying. This contributed to the decreases in overstory cover at LB and MB from July to September. Although mortality was noted at HB, a steady increase in crown cover occurred throughout the growing season. The gaps which were created were quickly exploited by adjacent canopy

Figure 6. Mean percent canopy cover per plot during May, July and September, 1992.

CANOPY COVER



trees and as a result coverage steadily increased through-out the growing season. The mortality was highest at HB early in the season. Mortality occurred at MB and HB later. The steady cover at UB may indicate a steady-state condition.

A negative correlation was found between crown cover and herbaceous layer cover ($r=-.5$; $p=.09$). Although this correlation was not significant at 95% probability level, the data does suggest a trend. The following equation was calculated to predict herbaceous layer cover from densiometer readings:

$$\%\ \text{Herbaceous Cover} = 2.30979 + -2.148368\ (\%\ \text{Canopy Cover})$$

Herbaceous cover did increase with burn intensity possibly in response to crown openings. This may suggest that the increased solar input was a major influence in increasing herb cover but is not the single most important factor. The interaction between canopy cover, fertility and seed availability or composition may be more important than any single factor influencing the recovery of the herbaceous layer.

V. CONCLUSIONS

The greatest soil fertility was found at LB and the lowest at UB. The greatest single limiting factor was N in HB and MB soils. UB and LB soils exhibited overall low fertility. The fertility of burned soils was significantly greater than unburned soils. Unidentified factors, perhaps microbial in origin, were observed in the course of the fertility experiment.

At the end of the first growing season the greatest herbaceous cover was at HB and the least at UB. Species richness was greatest at HB and LB during the growing season. Richness and diversity changed least during the study at UB. The occurance of new species and the resulting cover changes were most similar through the growing season at UB and MB. HB and LB were not similar to each other or UB and MB at the end of the growing season. Both richness and diversity were greater in burned areas than unburned areas. Species richness and diversity were lowest at UB.

Mean canopy cover was greatest at UB and decreased with increasing burn intensity. Herbaceous cover and canopy cover were negatively correlated. An increase in herbaceous cover seems to be the result of interactions of factors found on site rather than any single factor.

Seedbank species were well-represented in the herbaceous layer. Some species found in the seedbank were not found in the herbaceous layer. This suggests that the seedbank may have more potential than is expressed in the herbaceous layer following wildfire.

LITERATURE CITED

Abrams, M.D. 1992. Fire and the development of oak forests. Bioscience 42(5):346-353.

_______ and G.J. Nowacki. 1991. Historical variation in fire, oak recruitment, and post-logging accelerated succession in central Pennsylvania. Bull. Torrey Bot. Club 119(1):19-28.

Armson, K.A. 1977. Forest soils: properties and processes. University of Toronto Press, Toronto.

Bouyoucos, G.J. 1951. A recalibration of the hydrometer method of making mechanical analysis of soils. Agron. J. 43:434-438.

Carvell, K.L. and W.R. Maxey. 1969. Wildfire adversely affects composition of cove hardwood stands. West Virginia Agricultural Experiment Station Bulletin 2(2):4-5.

Christensen, N.L. 1977. Fire and soil-plant nutrient relations in a pine-wiregrass savanna on the coastal plain of North Carolina. Oecologia(Berl.) 31:27-44.

Core, E.L. 1966. Vegetation of West Virginia. McClain Printing Co., Parsons, WV.

DeVivo, M.S. 1990. Indian use of fire and land clearance in the southern Appalachians. Pages 306-310 in Fire and the environment: ecological and cultural perspectives. U.S. For. Serv. Tech. Rep. SE-69.

Fuller, W.H., S. Shannon, and P.S. Burgess. 1955. Effect of burning on dertain forest soils of northern Arizona. For. Sci. 1:44-50.

Gaiser, L.N. 1951. Random sampling within circular plots by means of polar coordinants. J. For. 49:916-917.

Gilliam, F.S. 1988 Interactions of fire with nutrients in the herbaceous layer of a nutrient-poor coastal plain forest. Bull. Torrey Bot. Club 115(4):265-271.

_______ . 1991 The significance of fire in an oligotrophic forest ecosystem. Pages 113-122 in Fire and the environment: ecological and cultural perspectives. U.S. For. Serv. Tech. Rep. SE-69.

_______ , and N.L. Christensen. 1986. Herb-layer response to burning in pine flatwoods of the lower coastal plain of South Carolina. Bull. Torrey Bot. Club 113:42-45.

Gleason, H.A. and A. Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. The NY Bot. Garden. NY,NY.

Ingersol, C.A. and M.V. Wilson. 1990. Buried propagules in an old-growth forest and their response to experimental disturbances. Can. J. Bot. 68:1156-1162.

Knight, H. 1966. Loss of nitrogen from the forest floor by burning. Forestry Chronicle 42:149-152.

Lorimer, C.G. 1985. The role of fire in perpetuation of oak forests. Pages 8-25 in J.E. Johnson, ed. Challenges in oak management and utilization. Cooperative Extension Service, University of Wisconsin, Madison.

McGee, C.E. 1979. Fire and other factors related to oak regeneration. Pages 75-81 in H.A. Holt and B.C. Fischer, eds. Regenerating oaks in upland hardwood forests. John S. Wright Forestry Conference, Purdue University, Layfayette, IN.

Muller, R.N. and F.H. Bormann. 1976. Role of Erythronium americanum Ker. in energy flow and nutrient dynamics of a northern hardwood forest ecosystem. Science 193:1126-1128.

SAS. 1988. SAS introductory guide. 3rd ed. SAS Institute, Inc. Cary, NC. 99 p.

____. 1984. SAS user's guide: statistics. SAS Institute, Inc. Cary, NC. 584 p.

Schiffman, P.M. and W.C. Johnson. 1992. Sparse buried seed bank in a southern Appalachian oak forest: implications for succession. Am. Midl. Nat. 127:258-267.

Siccama, T.G., F.H. Bormann, and G.E.Likens. 1970. The Hubbard Brook ecosystem study; productivtiy, nutrients, and phytosociology of the herbaceous layer. Ecological Monographs 40(4):389-402.

Spurr, S.H. and B.V. Barnes. 1980. Forest ecology. 3rd ed. John Wiley and Sons, New York.

Strausbaugh, P.D. and E.L. Core. 1977. Flora of West Virginia. 2nd ed. Seneca Books, Grantsville, WV.

Thompson, K. and J.P. Grime. 1979. Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. J. Ecol. 67:893-921.

U.S. Army Corps of Engineers. 1974. Environmental impact statement, Beech Fork Lake, Beech Fork Creek, Twelve Pole Creek basin, Cabell-Wayne counties, WV. U.S. Army Engineer District, Huntington, WV. 64p.

Van Lear, D.H. 1990. Fire and oak regeneration in the southern Appalachians. Pages 15-21 in Fire and the environment: ecological and cultural perspectives. U.S. For. Serv. Tech. Rep. SE-69.

Whittaker, R.H. 1966. Forest dimensions and production in the Great Smoky Mountains. Ecology 47(1):103-121.

Wright, H.A. and A.W. Bailey. 1982. Fire ecology: United States and Canada. John Wiley and Sons. New York.

Zak, D.H., P.M. Groffman, K.S. Pregitzer, S. Christensen and J.M. Tiedje. 1990. Ecology 71(2):651-656.

APPENDIX I

Seedbank Species Information

APPENDIX I. Species identified during May and August evaluations of the forest floor (seedbank) samples.

	UB		LB		MB		HB	
Species	May	August	May	August	May	August	May	August
Acalypha rhomboidea	X	X					X	X
Acer saccharum	X	X						
Ailanthus altissima					X	X	X	X
Andropogon virginicus		X				X		X
Antennaria plantaginifolia	X	X			X		X	X
Aster infirmus			X	X				
Aster prenantheoides	X	X						
Carex spp.	X	X	X	X	X	X	X	X
Carex willdenowii	X	X	X	X	X	X	X	X
Cercis canadensis	X	X		X			X	X
Coreopsis major			X	X	X		X	X
Cunila origanoides			X	X	X	X	X	X
Danthonia spicata					X	X		
Dentaria laciniata	X							

	UB		LB		MB		HB	
Species	May	August	May	August	May	August	May	August
Desmodium canadense			X		X			
Digitaria sanguinalis				X				
Erechtites hieracifolia	X	X	X				X	X
Erigeron strigosus	X	X						
Eupatorium serotina	X	X	X	X				
Fagus grandifolia				X				
Galium circaezans		X	X	X				
Galium lanceolatum	X	X						
Gallenia stipulata					X			
Geum virginianum					X			
Gnaphalium sp.								X
Hedeoma pulegioides								X
Helianthus microcephalus				X				
Heuchera americana	X	X	X	X			X	X
Hieracium sp.			X	X		X		
Houstonia longifolia				X				

	UB		LB		MB		HB	
Species	May	August	May	August	May	August	May	August
Hypericum mutilum		X						
Lactuca spp.	X	X						
Lespedeza cuneata			X	X		X		
Liriodendron tulipifera	X	X	X	X			X	X
Lobelia inflata		X						
Lonicera japonica	X	X				X		
Monarda spp.			X					
Morus rubra								X
Oxalis stricta	X	X						
Parthenocissus quinquefolia	X	X					X	X
Panicum clandestinum		X	X	X	X		X	X
Panicum spp.	X	X	X	X	X	X	X	X
Phytolacca americana					X	X	X	X
Polygala sanguinea								X
Polygonatum biflorum			X	X	X			
Potentilla simplex			X	X		X	X	X

	UB		LB		MB		HB	
Species	May	August	May	August	May	August	May	August
Prenanthes serpentaria	X	X				X		
Rhus copallina						X	X	X
Rhus glabra					X	X	X	X
Rhus radicans			X	X			X	X
Robina pseudo-acacia						X		
Rosa canina							X	X
Rosa carolina			X	X			X	X
Rubus spp.	X	X	X	X	X	X	X	X
Sassafras albidum	X	X	X		X	X	X	X
Scutellaria incana	X		X	X				
Smilacina racemosa							X	X
Smilax rotundifolia					X	X		
Specularia perfoliata								X
Trifolium pratense							X	X
Tussilago farfara						X		
Ulmus rubra	X	X						

	UB		LB		MB		HB	
Species	May	August	May	August	May	August	May	August
Uvularia sessilifolia			X	X	X			
Vaccinium vacillans			X	X	X	X	X	X
Viburnum acerifolium			X	X				
Viola papilionacea	X	X	X	X	X	X	X	X
Vitis spp.	X	X	X	X			X	X

APPENDIX II

Herbaceous Species Information

APPENDIX II. Species identified during the May, July and September, 1992 samples.

HERBACEOUS LAYER SPECIES

Species	Common	Occurrence	Comments
Acer saccharum Marsh	Sugar Maple	UB,LB	Rich woods
Acer rubrum L.	Red Maple	UB,LB,MB,HB	Moist woods
Allium spp.	Wild Onion	UB	Various habitats
Ailanthus altissima (Mill.) Swingle	Tree-of-Heaven	HB	Second-growth hardwood stands
Andropogon virginicus L.	Broomsedge	MB,HB	Abandoned farmland
Antennaria neglecta Greene	Field Pussytoes	LB	Dry fields, roadsides
Antennaria plantaginifolia (L.) Richards	Plantainleaf Everlasting/ Pussytoes	LB,HB	Dry soil Open woods
Arisaema triphyllum (L.) Schott	Jack-in-the-pulpit	UB	Rich woods and thickets
Arthraxon hispidus (Thunb.) Makino	No common name	LB,HB	
Asimina triloba (L.) Dunal.	Pawpaw	UB	Moist,rich soils
Aster infirmus Michx.	White Aster	LB,MB,HB	Open woods
Botrychium virginianum (L.) Sw.	Rattlesnake Fern	UB	Rich woods
Carex pensylvanica Lam.	Sedge	LB,MB,HB	Sunny,open woods
Carex spp.	Sedge	UB,LB,MB,HB	Sunny,open woods
Carex willdenowii Schkuhr.	Sedge	MB,HB	Dry woods, acid soils

Carya ovata (Mill.) K. Koch	Shagbark Hickory	UB,LB,MB,HB	Rich soil on hillsides
Carya tomentosa Nutt.	Mockernut Hickory	UB,LB,MB,HB	Rich soil on hillsides
Cassia nictitans L.	Wild Sensitive Plant	MB,HB	Sandy soils
Caulophyllum thalictroides (L.) Michx.	Blue Cohosh	UB	Rich woods
Celtis occidentalis L.	Hackberry	UB	Rich or dry soils
Cercis canadensis L.	Redbud	UB,LB,MB,HB	Rich soil
Chimaphila maculata (L.) Pursh.	Spotted Wintergreen	MB, LB	Open woods
Cornus florida L.	Flowering Dogwood	UB,LB,MB,HB	Dry woods
Coreopsis major Walt.	Wood Tickseed	LB,MB	Dry woods, clearings
Corydalis flavula (Raf.) DC.	Yellow Corydalis	LB,MB	Rocky woods
Desmodium canadense (L.) DC.	Sticktight	LB,MB	Open woods, streambanks
Dicentra cucullaria (L.) Bernh.	Dutchman's Breeches	UB	Rich woods
Digitaria sanguinalis (L.) Scop.	Crabgrass	LB	Waste places
Dioscorea quaternata (Walt.) J.F. Gmel.	Four-leaved Wild Yam	UB,LB,MB	Thickets
Duchesnea indica (Andr.) Focke	Indian Strawberry	UB	Waste places
Epilobium angustifolium L.	Fireweed	LB,MB	Newly burned lands
Erechtites hieracifolia (L.) Raf.	Fireweed	LB,MB,HB	Woods,waste places, thickets

Erigeron strigosus Muhl.	Daisy Fleabane	LB	Fields, waste places
Eupatorium serotinum Michx.	Late-flowering Thoroughwort	LB,MB,HB	Damp to dry thickets
Fragaria virginiana Duchesne	Virginia Strawberry	LB,MB,HB	Dry soil
Galium circaezans Michx.	Wild Liquorice	LB,HB	Dry woods
Galium lanceolatum Torr.	Lanceleaf Wild Liquorice	UB,LB,MB,HB	Dry Woods
Gallinia stipulata		LB,MB,HB	
Geum virginianum L.	Virginia Avens	UB,LB,MB,HB	Dry woods
Gnaphalium obtusifolium L.	Cudweed	MB	Fields, open places
Hedeoma pulegioides (L.) Pers.	American Penny Royal	LB,MB,HB	Dryfields, banks
Heuchera americana L.	Alumroot	LB,MB,HB	Dry or rocky woods
Hieracium spp.	Hawkweed	LB,MB,HB	Fields, waste places
Houstonia longifolia Gaertn.	Long-leafed Summer Bluets	LB	Dry, open places
Lespedeza cuneata (Dumont) G. Don	Lespedeza	LB,MB,HB	Fields, roadsides
Lespedeza intermedia (S. Wats.) Britton	Lespedeza	LB,MB,HB	Open, rocky woods
Lindera benzoin (L.) Blume	Spicebush	UB,LB,HB	Damp woods
Liriodendron tulipifera L.	Yellow-Poplar	UB,LB,MB,HB	Rich soils
Lonicera japonica L.	Japanese Honeysuckle	UB,LB,MB,HB	Fields, thickets
Morus rubra L.	Red Mulberry	MB,HB	Rich woods
Oxalis stricta L.	Upright Yellow Wood Sorrel	LB,MB,HB	Dry open woods

Panicum clandestinum L.	Deertongue Grass	LB,MB,HB	Moist,sandy soils
Panicum dichotomum L.	Bushy Panic Grass	LB,MB,HB	Dry,open acid woods
Panicum gattingeri Nash	Tickle-grass	HB	Waste places and open ground
Panicum sp.	Panicum	HB	Open areas
Parthenocissus quinquefolia (L.) Planch	Virginia Creeper	UB,LB,MB,HB	Thickets, fencerows and hillsides
Phytolacca americana L.	Polkweed	LB,MB,HB	Rich soils
Pinus virginiana Mill.	Virginia Pine	LB,MB,HB	Poor,dry soil
Plantago virginica L.	Dwarf Plantain	MB	Dry,sandy soil
Poa spp.	Bluegrass	LB,MB	Various sites
Podophyllum peltatum L.	May-apple	UB	Rich woods thickets
Polygala verticillata L.	Whorled Milkwort	HB	Poor, dry soil
Polygonatum biflorum (Walt.) Ell.	Common Solomon's Seal	LB	Woods and thickets
Polygonum persicaria L.	Lady's Thumb	MB	Damp,waste places
Polystichum acrostichoides (Michx.) Schott.	Christmas Fern	UB	Woods and rocky hillsides
Prenanthes serpentaria Pursh	Rattlesnake-root	UB	Thickets and open woods
Prunus serotina Ehrh.	Wild Black Cherry	UB	Woods

Quercus alba L.	White Oak	LB	Rich, moist soil
Quercus prinus L.	Chestnut Oak	LB,MB,HB	Dry, shaly hillsides, ridges
Quercus velutina Lam.	Black Oak	UB,LB,MB,HB	Dry soil on slopes
Rhus copallina L.	Winged Sumac	MB,HB	Abandoned fields, rocky hillsides
Rhus glabra L.	Smooth Sumac	MB,HB	Dry soil
Rhus radicans L.	Poison Ivy	LB,MB,HB	Disturbed areas, waste places
Rhus typhina L.	Staghorn Sumac	MB,HB	Open hillsides
Robinia pseudo-acacia L.	Black Locust	MB,HB	Various habitats
Rosa carolina L.	Pasture Rose	LB,MB,HB	Dry, sandy or rocky places thin woods
Rubus spp.	Blackberry/ Raspberry	UB,LB,MB,HB	Waste places various habitats
Sassafras albidum (Nutt.) Nees	White Sassafras	UB,LB,MB,HB	Thickets, second-growth woods
Saxifraga virginiensis Michx.	Early Saxifrage	MB,HB	Dry, rocky woodlands
Scutellaria incana Biehler	Downy Skullcap	HB	Moist or dry woods, thickets
Sedum ternatum Michx.	Wild Stonecrop	LB,HB	Damp, rocky places
Senecio obovatus Muhl.	Squaw-weed	LB,MB,HB	Moist soil, on banks, in woods

Senecio spp.	Squaw-weeds/ Ragworts	LB,MB	Various habitats
Smilacina racemosa (L.) Desf.	False Solomon's Seal	UB,LB	Moist woods, thickets
Smilax glauca Walt.	Saw Brier	UB,MB	Dry thickets old fields
Smilax rotundifolia L.	Common Greenbrier	UB,LB,MB,HB	Thickets, thin woods
Solidago rugosa Ait.	Wrinkled-leaf Goldenrod	MB,HB	Fields,road-sides, thickets
Specularia perfoliata (L.) A.DC.	Venus' Looking Glass	LB,MB,HB	Dry woods, fields
Thalictrum dioicum L.	Early Meadowrue	UB	Rocky woods
Trifolium pratense L.	Red Clover	HB	Thin woods, fields, meadows
Ulmus rubra Muhl.	Red Elm/ Slippery Elm	UB	Rich soils
Uvularia sessilifolia L.	Sessile-leaved Bellwort	LB	Dry to moist woods/ thickets
Vaccinium vacillans Torr.	Late Low Blueberry	LB,MB,HB	Dry places
Verbena urticifolia L.	Nettleleaf Vervain	UB,LB,MB,HB	Thickets, Waste grounds
Viburnum acerifolium L.	Maple-leaf Arrowwood	LB,MB,HB	Dry rocky woods
Viola papilionacea Pursh	Common Blue Violet	UB,LB,MB,HB	Disturbed, open areas
Viola pensylvanica Michx.	Smooth Yellow Violet	LB,MB,HB	Moist,open woods
Vitus spp.	Wild Grapevine	UB,LB,MB,HB	Woods, thickets