ABSTRACT

WILLIS, MEGAN S. Status and Soil Requirements of *Rhus michauxii* in North Carolina. (Under the direction of Richard Braham, Charles Davey, and John King.)

This study mapped natural *Rhus michauxii* populations located in North Carolina and determined that NC populations are declining. Soil analysis at 44 populations and sub-populations revealed that soils are an important factor, but they are not the sole limiting factor. A greenhouse study which involved growing *Rhus michauxii* in different soil media determined that 50% clay and 50% loam is the best host soil.

Status and Soil Requirements of *Rhus michauxii* in North Carolina

by
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BIOGRAPHY

Megan S. Willis was born in the rural town of Raeford, North Carolina on November 10, 1981. She attended Hoke County High School from which she graduated with honors in 2000. In the fall of that year she began college at Mars Hill College in the mountains of western North Carolina. At the start of her sophomore year she transferred to the University of North Carolina at Asheville. Here she completed a B.S. in Environmental Science in 2004 with a concentration in Natural Resource Management. After graduation, she accepted a position with the North Carolina Department of Transportation (NCDOT) as an Environmental Specialist in Raleigh, North Carolina. In the fall of 2005 she began graduate school seeking an M.S. in Forestry at North Carolina State University.

ACKNOWLEDGEMENTS

A special thanks to North Carolina Department of Transportation for their collaboration on the Richmond County (TIP R-2502) transplant/mitigation project involving Michaux's sumac and for providing materials necessary for my study. I would also like to thank my committee members, the NC Natural Heritage Program, my co-workers and my family for all their support.

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INTRODUCTION

Michaux's sumac (*Rhus michauxii* Sarg.), also known as dwarf sumac or false poison sumac, is an endangered federally-protected shrub in the family Anacardiaceae. It can easily be identified from other sumacs by its short stature of only 0.3-0.9 m and its densely pubescent leaves and stem (Emrick 2003). Michaux's sumac contains pinnately compound leaves each with 7-13 oblong, evenly serrated leaflets. The flowers are small, greenish-yellow in color, grow in terminal clusters, and later form bright red drupes (Murdock and Moore 1993).

Michaux's sumac is a clonal shrub that reproduces vegetatively from adventitious stems formed along the roots. Each plant is capable of producing numerous shoots throughout a wide area creating a complex underground system of connected plants (Braham et al. 2006).

The plant was first discovered in Mecklenburg County (now Union County) in 1794 by Andre Michaux. In 1803 he named it *Rhus pumila*, but this name was later found to be a homonym. As a result, Sargent renamed it *Rhus michauxii* in 1895 to honor its discoverer. The original type specimen collected by Michaux is located in the Michaux Herbarium in Paris, France (Barden 2004).

Several factors likely contribute to the rarity of Michaux's sumac, including strict habitat requirements, low reproductive capacity, hybridization with similar species (mostly *Rhus copallina L.*), and dependence on fire. Early reports reveal that the plant was never common (Boynton 1901, Murdock and Moore 1993). The species was originally believed to require sandy, well-drained, acidic soils with a low cation exchange capacity (Murdock and

Moore 1993); however recent population discoveries suggest that a wider range of soil properties may be suitable for *Rhus michauxii* (Emrick 2003). One factor believed to be essential is an open canopy, usually created through disturbance. Historically this habitat was maintained through regular fire events; however fire suppression, development, and agriculture have nearly eliminated this community (Braham and Suiter 2000).

The recovery plan created for *Rhus michauxii*, by the United States Fish and Wildlife Service, requires that 19 self-sustaining populations must be identified and protected for long-term survival before the species can be considered recovered (Murdock and Moore 1993). Actions suggested by the recovery plan to aid in recovery include: 1) locating additional populations, 2) monitoring and protecting existing populations, 3) conducting research on the biology of the species, 4) establishing new populations or rehabilitating marginal populations, and 5) investigating and conducting necessary management activities at all 19 sites (Murdock & Moore 1993).

The project described here addresses two parts of the recovery plan, monitoring and establishing new populations. Monitoring existing populations is important because it documents the current status and stability of populations, but over the years monitoring has been haphazard. At best, populations have been monitored nine times. At worst, they have been monitored only once (NCNHP 2007), because funding limitations prevented regular visits to all sites. As a result, North Carolina Natural Heritage Program (NCNHP) often relies on volunteers to update reports. Since the level of training varies among volunteers, the reports are inconsistent and sometimes incomplete. Accurate and timely information on the status of the plant is needed to determine whether the recovery plan is succeeding. To date, 57 populations have been identified in North Carolina (Figure 11); however 21 of these are believed to be extirpated (NCNHP 2007).

The recovery goal of establishing new populations from transplanting has had mixed results (Boyer 1993, Braham et al. 2006). Scarce literature on Michaux's sumac and rare plants in general makes developing suitable methods difficult. Although one transplanting effort was ultimately successful, survivorship of the original propagules was low both in the field and in the greenhouse (Braham et al. 2006). We hypothesize that better information on suitable host soils would improve survivorship and conservation efforts.

OBJECTIVES

This project had three objectives: 1) updating the information for each known natural Michaux's sumac population in NC, 2) characterize the soils at all known natural populations in NC, and 3) determine which host soils are most suitable.

METHODS

Part 1: Updating the information for each known natural Michaux's sumac population in NC.

Fifty-seven natural populations of Michaux's sumac have been identified since 1794. These populations have been monitored more recently using the NCNHP Element Occurrence (EO) criteria which include: geographic location, the number of plants found during each visit, evidence of reproduction, associated species, and management needs. I visited 42 sites between May 2005 and September 2006 and all information in each EO document was updated. Ten historical populations and two populations thought to be extirpated for at least 15 years were not visited because of the inability to identify the locations of the plants. Experimental populations were not included in this study because they do not currently count towards the 19 populations needed for recovery. One population located on the Fort Bragg reservation was not visited because of its location within an artillery impact area. One additional population could not be located because of a lack of GPS coordinates.

The number of plants observed over time was plotted for each site with three or more visits to research possible trends. Sites divided into sub-populations were not included because frequent confusion between the different sub-populations resulted in inaccurate counts. Populations that had been augmented with additional plants were also not included because it was impossible to differentiate between planted and natural individuals. In the future if populations are sub-divided, they should be documented in separate reports with precise location information for each. A table of all populations, locations and number of observations is found in Appendix 4.

Part 2: Characterizing the soils at known populations in NC.

To obtain more information on the native host soils of Michaux's sumac, soil samples were taken using an auger 2.5 cm wide to a depth of 20 cm at each known population in NC. Each sample was taken within 1 m of a plant, unless no plants were currently found at that site. If no plants were found, yet had been found at that site within the past seven years, soil samples were taken at the GPS coordinates noted on the EO. All soil samples were placed in plastic bags and then transferred to cardboard boxes. Soil samples were analyzed by the

North Carolina Department of Agriculture, Agronomics Division (NCDA Agronomics) Soil Testing Laboratory to determine soil reaction (pH), available macro-nutrients (meq/100 m^3 of Ca, Mg, P, K, and S) and availability of select micro-nutrients (meq/100 m^3 of Zn, Cu, and Mn).

Results of the nutrient analysis were compared with the number of plants at each site to look for correlations. Preliminary analysis indicated that the data were not normally distributed; therefore the log of the number of plants was used. A straight correlation using Pearson's correlation coefficients was performed using the CORR procedure in SAS. Since soil nutrients are typically dependent on one another, a multiple regression model with backward elimination was performed using the REG procedure to determine whether significant interactions between nutrients existed.

Part 3: Determining suitable host soils.

Because others have had difficulty identifying suitable host soils for transplanting populations (e.g., Thrush 2002, Emrick 2003, Braham 2006), I transplanted Michaux's sumac roots into several soil media. A total of 240 pieces of root each 15 cm long were collected from a single clone at a NCDOT Richmond County site in February 2006, using techniques developed by Braham et al. (2006). Roots were excavated using a hand trowel, starting at an above-ground stem and carefully following each root. The roots were placed in plastic bins filled with damp, shredded newspaper and sealed with snap-on lids to prevent desiccation. The bins were transported to North Carolina State University (NCSU) where they were kept in cold storage at 4 degrees C. To reduce the possible effect of variable starch content, only root pieces weighing 1-2 g were used. Root pieces were then assigned randomly to pots at the NCSU Method Road Greenhouses. Extra above-ground stems and roots that were excavated were taken by NCDOT and transplanted to other sites, not part of this study.

Three soil types (sand, clay, and loam) were collected from the NCDOT maintenance yard and the NCSU greenhouses. Soil textures were determined by performing a texture-feel analysis (Thein 1979). Seven different combinations of these three soils were mixed and placed into 15 pots each, for a total of 105 pots (Table 1). One root was planted in each pot at an approximate depth of 5 cm. Although Michaux's sumac has not been studied specifically, many other *Rhus* are dependent on endomycorrhizal fungi (Harley and Smith 1983). To help ensure mycorrhizal infection, approximately 15 cm^3 of native soil collected from the transplant site was added to each pot.

Soil from five of the 57 known populations was collected to use as comparisons (Table 1). Each collection was a distinctly different soil type. Negative results from previous greenhouse studies have been reported (Thrush 2002, Braham 2006); therefore I included native soils in which the plants were surviving for comparison purposes. Soil from each area was collected and sifted (2 mm stainless steel mesh) to remove large debris such as stones and roots. Soil was put into 20-cm diameter pots, each containing a 15-cm long section of root of approximately equal size and weight (1-2 g). This procedure provided 15 pots per soil type, for a total of 75 pots (Table 1).

Table 1. Soil media used in Michaux's sumac transplanting experiment.

Created Soil Media	No. of Pots	Soil From Native Populations	Population Locations	No. of Pots
100% Clay	15	EO 36, Sandy Clay Loam	Scotland County, Roadside	15
100% Loam	15	EO 16, Clay	Wake County, Roadside	15
100% Sand	15	EO 25, Sand	Moore County, Roadside	15
50% Clay/50% Loam	15	EO 5, Loam	Davie County, Roadside	15
50% Clay/50% Sand	15	EO 33, Loamy Sand	Hoke County, Ft. Bragg	15
50% Loam/50% Sand	15			
33% Clay/33% Sand/33% Loam	15			
Total	105			75

All potted plants were placed in the NCSU greenhouse on a raised gravel bed during the second week of March. The pots were placed randomly on the gravel bed to limit the location effect and were watered with a garden hose three times a week until saturated. After three weeks the roots began producing above-ground shoots. Plant height (from the top of the soil to top of the terminal bud) was measured to the nearest 1 mm weekly. Length of the longest leaf and the number of leaves on each plant were measured weekly after five weeks of growth. For plants with more than one stem, string was tied around the tallest shoot so that the same shoot could be measured throughout the study.

In the first week of June, each plant was treated with 28 g of granular Marathon to combat white flies (*Bemisia tabaci*). The second week of June, plants began to show signs of powdery mildew (Erysiphaceae), so they were placed outside on pallets. Moving plants outside has effectively combated powdery mildew in other studies (Braham et al. 2006). Unfortunately most plants began to decline and die soon after they were transferred outside. Three plants were taken to the NCSU Plant Disease and Insect Clinic to determine the cause of death, however no evidence of disease, insects, or fungus was found. Grand (2006), concluded that it was likely a combination of stresses, including white fly, powdery mildew, and root rot due to several large rain events (see Appendix 5) during the first several weeks outside. To prevent this mortality from affecting the soil experiment, only the data collected in the greenhouse (a period of ten weeks) was used.

The percentage of roots that sprouted in each soil type was compared and a test of means using the GLM procedure in SAS was performed to determine if the means were significantly different. The greenhouse data were also analyzed using a frequency procedure to examine the distribution of the heights of plants at week ten. An analysis of covariance of growth over all ten weeks was performed using the Mixed procedure for height and length of the longest leaf. The number of leaves was a decidedly poor measure of plant vigor because as plants became more vigorous, their newer leaves became larger and shaded the original leaves which were shed. Therefore the number of leaves was not included in the analysis.

RESULTS AND DISCUSSION

Part 1: Updating the information for each known Michaux's sumac population in NC.

A total of ten populations were without sub-populations, non-augmented, and had three or more documented visits. The number of plants counted at each visit was plotted over time for each site, to determine a positive or negative trend (Figures 1-10). Only two populations had a positive slope and one was stable, suggesting that Michaux's sumac is declining in North Carolina, despite low r^2 values for some regressions. The two populations with a positive slope are located adjacent to roads and the one stable population is in an old road bed, suggesting that the disturbance created by roadside activities is beneficial. Other observers have also noted the correlation between increasing plant counts and disturbance (Boyer 1993, Murdock and Moore 1993). Historically Michaux's sumac was disturbed regularly by fire (Boyer 1993, Braham et al. 2006).

The regression for EO 5 (Figure 1) suggests the population is increasing, but the population was actually extirpated in 2001 by herbicide sprayed by a local utility company. This situation exemplifies the vulnerability of some populations, and the need for more protected populations to be established.

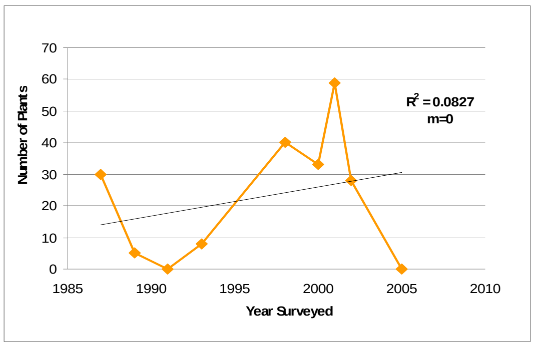

Figure 1. Michaux's sumac timeline for EO 5 in Davie County on Puddington Road.

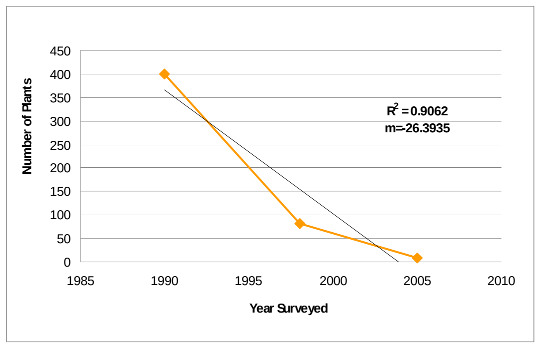

Figure 2. Michaux's sumac timeline for EO 7 in the Sandhills Game Lands.

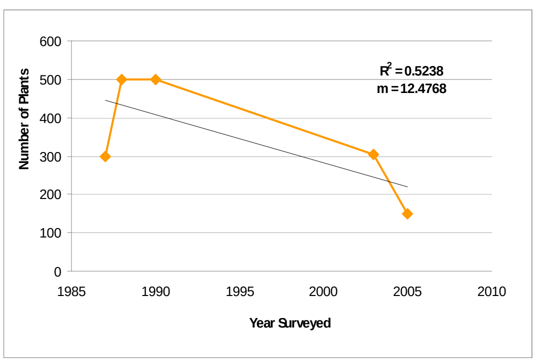

Figure 3. Michaux's sumac timeline for EO 8 in Hoke County bordering field.

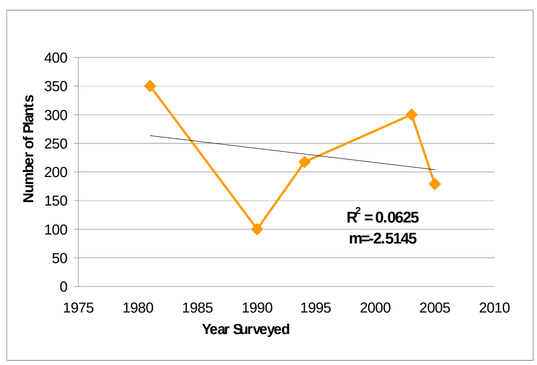

Figure 4. Michaux's sumac timeline for EO 12 in the Sandhills Game Lands.

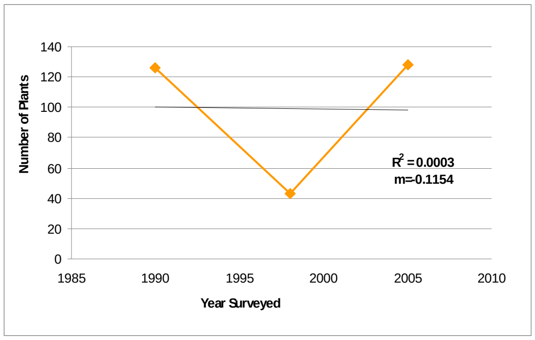

Figure 5. Michaux's sumac timeline for EO 13 in the Sandhills Game Lands.

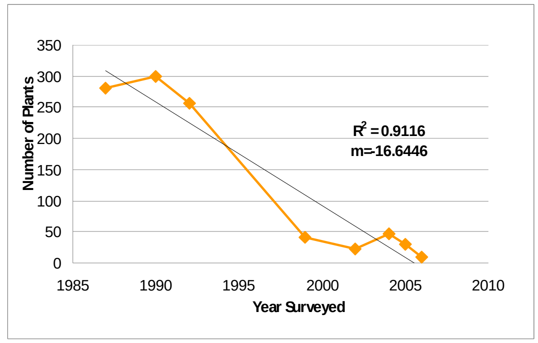

Figure 6. Michaux's sumac timeline for EO 16 in Wake County along roadside.

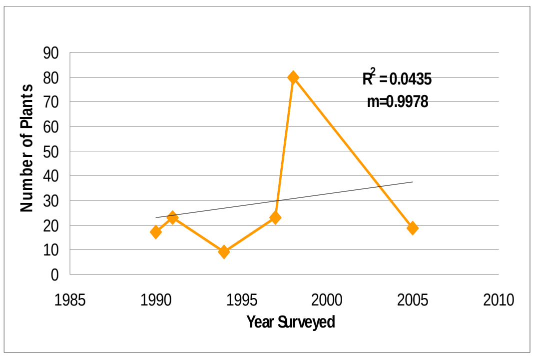

Figure 7. Michaux's sumac timeline for EO 25 in Moore County along roadside.

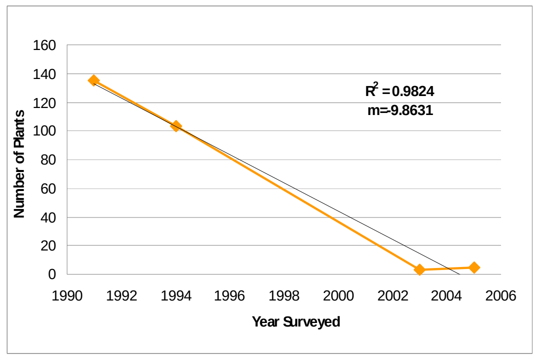

Figure 8. Michaux's sumac timeline for EO 28 in the Sandhills Game Lands.

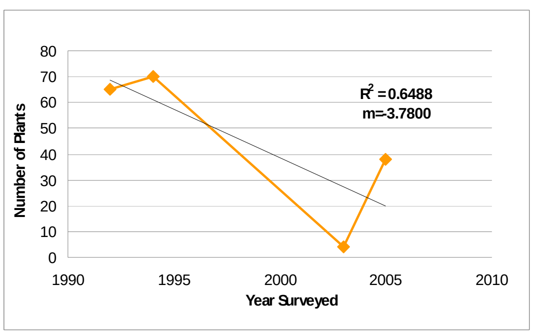

Figure 9. Michaux's sumac timeline for EO 35 in the Sandhills Game Lands.

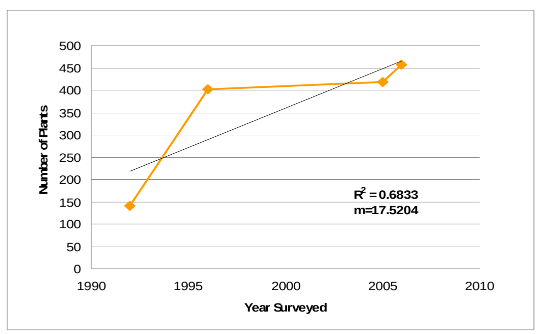

Figure 10. Michaux's sumac timeline for EO 36 near Drowning Creek along roadside.

The 32 remaining populations were not used in the regression analysis, but they were examined for possible trends. Fifty-nine percent (19 populations) had a positive trend, 38% (12 populations) had a negative trend, and 3% (1 population) were stable (Appendix 4). The majority of populations had a positive trend, yet because of the reasons listed previously (populations were visited less than 3 times, populations were augmented, or confusion because of sub-population differentiation) I believe these data are not reliable enough to draw any conclusions. Of the 42 total populations visited, 23 populations had a positive trend or were stable and 19 populations were declining.

A map was used to compare the current number of Michaux’s sumac populations to the total number of populations (experimental populations excluded) in North Carolina. To date, 57 natural populations have been identified in North Carolina since 1794 (Figure 11). The number of populations currently surviving in North Carolina is 36 (Figure 12), a decline of 37% over 214 years. Also the number of counties containing populations have declined from 15 to 7 and the number of populations in the remaining counties have declined by 30% on average. The majority of populations still thriving are in Richmond, Scotland, Hoke and Moore Counties; located in protected areas (Sandhills Game Lands, Camp McCall and Fort Bragg Reservation) which are burned frequently. I believe this signifies the need for more populations to be protected and managed. Overall, my results suggest Michaux’s sumac is declining in North Carolina.

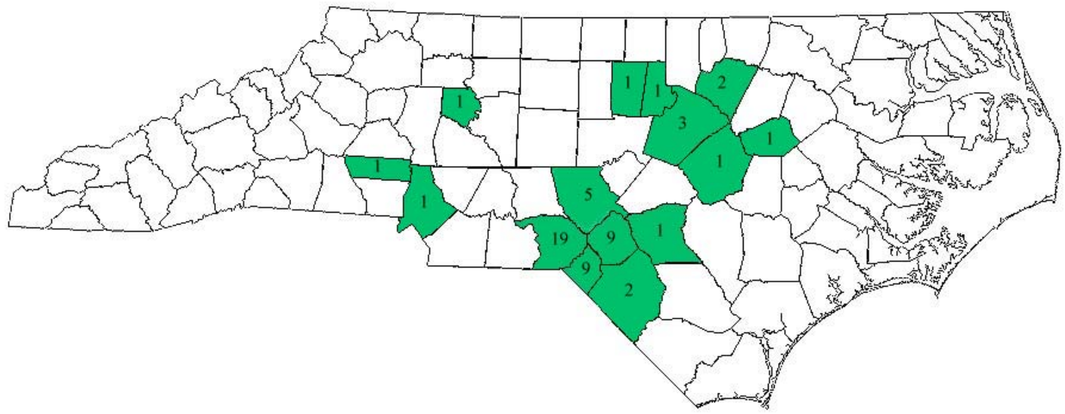

Figure 11. Historical and current natural Michaux's sumac population locations within NC.

* Number within county boundaries depicts the number of populations in that county.

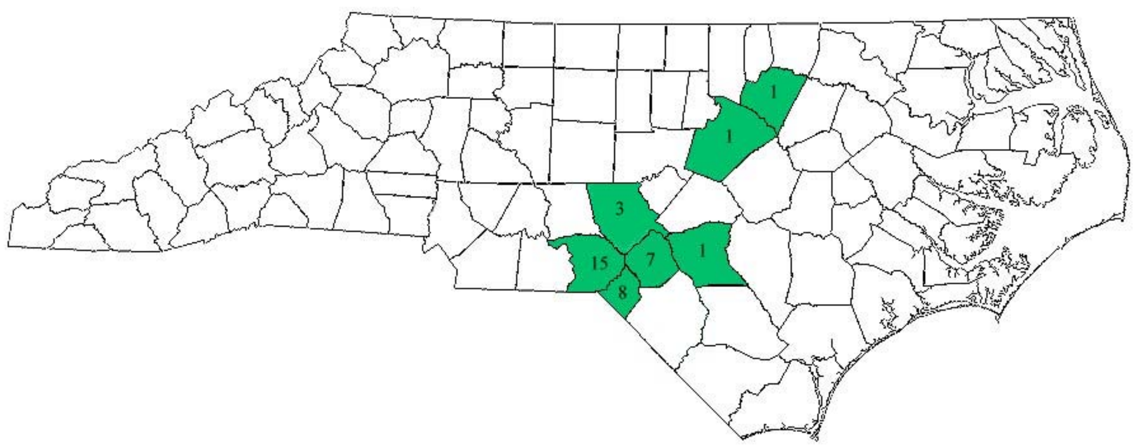

Figure 12. Current natural Michaux's sumac population locations within NC.

* Number within county boundaries depicts the number of populations in that county.

Part 2: Characterizing the soils at known populations in NC.

Results of the nutrient analyses were compared with the number of plants at each site to determine if a relationship existed between nutrients and population size. Three nutrients were found to be statistically correlated to abundance: high levels of magnesium (p=0.0538), high levels of manganese (p=0.0385), and low levels of zinc (p=0.0192).

High levels of magnesium can be explained by the low levels of phosphorus. Magnesium and phosphorus typically compete for positions on cation exchange sites and since phosphorus is limited, there are more sites available for magnesium (Fisher and Binkley 2000). Thus more magnesium is available to plants because less leaches out of the soil.

Adequate levels of manganese were expected since it becomes more soluble in acidic soils (Fisher and Binkley 2000), but that did not explain the very high levels which were found. Davey (2008) suggested that manganese is correlated with moisture retention even for short time periods. Although most of our soils are very sandy, a large majority of the plants were found in pea swells, slight depressions in flat terrain which over the short term accumulate moisture and over the long term accumulate nutrients (Sorrie 2007). This correlation suggests that Michaux's sumac needs the additional water and nutrients retained in pea swells. Thus new populations should be established on similar sites if the substrate in the area is primarily sand.

Low levels of zinc are frequently correlated with sandy substrate in which the majority of *Rhus michauxii* populations occur. Typically zinc deficiency results in stunted growth, thin stems, reduced leaf size, and chlorosis of the leaves (Hacisalihoglu and Kochian 2003). Since these symptoms were not observed during this study, we can conclude that *Rhus michauxii* has adapted to these conditions and developed zinc efficiency. Because only a select number of plants have this ability, competition is reduced in areas with zinc deficient soils.

The regression model predicted five significant main effect nutrients and six significant nutrient interactions ($r^2 = 0.7457$, Table 2) using a confidence interval of 0.1.

Table 2. Parameter estimates for soil nutrients at Michaux's sumac populations.

Variables	**DF**	**Parameter Estimate**	**Standard Error**	**t-value**	**Pr>t**
Intercept	1	6.83423	9.9308	0.69	0.4974
pH	1	-0.79676	2.05221	-0.39	0.7010
Ca	1	-0.0015	0.00461	-0.33	0.7468
Mg	1	0.65341	0.16013	4.08	0.0004
P	1	0.94471	0.31614	2.99	0.0061
Mn	1	-0.00273	0.00089	-3.07	0.0050
Zn	1	-1.24829	0.2865	-4.36	0.0002
S	1	-0.51349	0.27873	-1.84	0.0769
pH/Ca	1	0.00252	0.00081	3.11	0.0045
pH/Mg	1	-0.13189	0.03099	-4.26	0.0002
pH/P	1	-0.18925	0.06355	-2.98	0.0062
pH/Zn	1	0.24815	0.05581	4.45	0.0001
pH/S	1	0.11392	0.05872	1.94	0.0633
Ca/S	1	-0.00022	0.00004	-5.37	0.0001

The model predicts three of the same straight correlations (Mg, Mn & Zn) as the correlation analysis but also includes phosphorus for extremely low values. Thirty-two sites contained phosphorus values of zero, but this result does not mean phosphorus was absent, only that the amounts were not detectable. Also the soil test only detects mineral phosphorus not organic phosphorus which leaches slowly from organic matter. The correlation between plant numbers and low phosphorus levels might exist because of the reduced competition from herbaceous plants and overstory trees (Fisher and Binkley 2000). Less competition increases the available sunlight. A similar situation occurs with turkey oak (*Quercus laevis* Walt.) which occurs primarily on dry, sandy, nutrient-poor sites because it is not competitive on more productive sites (Miller and Lamb 1985).

Five significant interactions were found between nutrients, including two additional nutrients (calcium and sulfur). These interactions were expected since soil acidity determines the availability of these nutrients (Pritchett and Fisher 1987).

This analysis suggests that soil nutrients are important in determining where Michaux's sumac grows. This result was expected since Michaux's sumac only grows in a limited number of areas. Before new populations are established, the soil should be analyzed to see if nutrient deficiencies exist (Table 3) although the plants can survive in a wide range of acidities and nutrient levels. The mean nutrient values (Table 3) can be used as a general guide, but in some populations they were inadequate for robust growth. Phosphorus, potassium, and zinc were frequently deficient, as defined by NCDA, yet the plants survived. Future transplant projects should consider sites with low levels of phosphorus, potassium and zinc to reduce competition for the plant. Future studies should consider using a soil testing lab which tests for boron, since these sandy soils are frequently deficient.

Table 3. Soil nutrient values for survival of Michaux's sumac populations.

	pH	**Ca (kg/ha)**	**Mg (kg/ha)**	**P-I**	**K-I**	**Mn-AI**	**Zn-AI**	**Cu-I**	**S-I**
High	7.3	8206	1660	122	43	859	164	139	124
Low	4	125	25	0	5	28	0	9	14
Mean	5.1	706.0	101.2	10.5	13.9	298.9	23.2	39.5	40.9
Nutrient Deficiency		< 25	< 9	< 10	< 20	< 30	< 20	< 20	<25

I – nutrient index as used by the NCDA Soil Testing Lab.
AI – nutrient availability index as used by the NCDA Soil Testing Lab.

Part 3: Determining suitable host soils.

The first assessment compared the percent of roots that sprouted in each soil type (Figure 13). The highest sprouting occurred in 50% clay/50% loam, 100% loam, and 33% sand/33% loam/33% clay. The test of means performed on the survival data (Table 4) found that although some overlap exists, the two soils with the highest survival were significantly different from the two soils with the lowest survival.

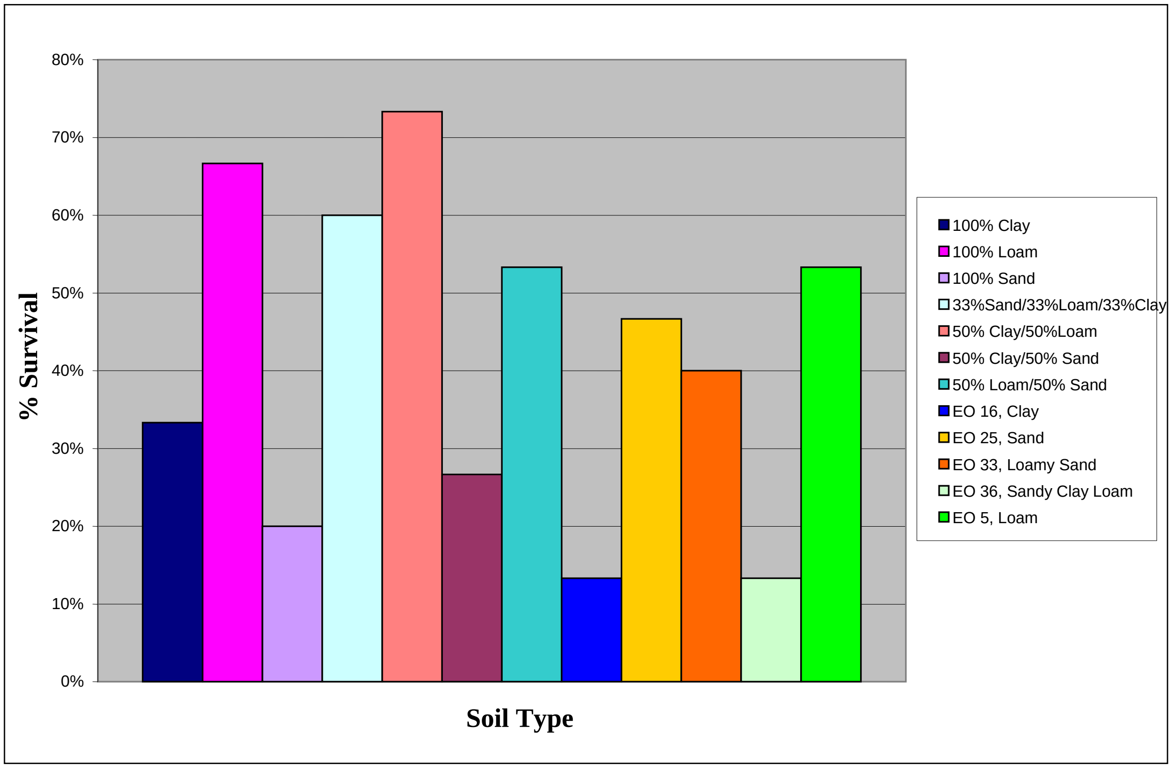

Figure 13. Sprouting of Michaux's sumac in different soil media.

Table 4. Mean sprouting of Michaux's sumac roots in different soil media.

Grouping				Mean	N	Soil Type
		A		0.7333	15	50% Clay/50% Loam
		A		0.7333	15	100% Loam
	B	A		0.6000	15	33% Sand/33% Loam/33% Clay
	B	A	C	0.5333	15	50% Loam/50% Sand
	B	A	C	0.5333	15	EO 5
D	B	A	C	0.4667	15	EO 25
D	B	A	C	0.4000	15	EO 33
D	B		C	0.3333	15	100% Clay
D	B		C	0.2667	15	50% Clay/50% Sand
D	B		C	0.2667	15	EO 16
D			C	0.2000	15	100% Sand
D				0.1333	15	EO 36

The highest survival rate (73%) is similar to the highest survival noted in three other studies (Boyer 1993, 1996; Braham et al. 2006). This suggests that approximately 75% survival is the highest one can expect when transplanting Michaux's sumac.

I expected that loam soils would provide higher survival than sand or clay, because of its intermediate water holding capacity, productive cation exchange capacity, aeration, and nutrient retention (Pritchett and Fisher 1987). I did not expect the native soils to perform worse, suggesting that soils are not the most-limiting factor.

The frequency analysis revealed that the data are heavily skewed to the left (Figure 14) because a large number of roots did not sprout. Therefore the plants that did not sprout were removed from the two final analyses (Figure 15).

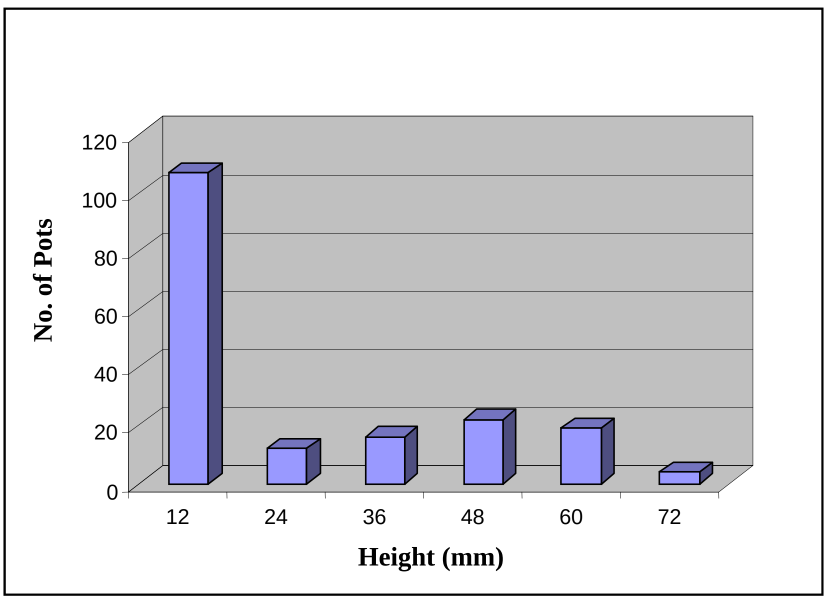

Figure 14. Histogram of the height of all Michaux's sumac plants at week 10.

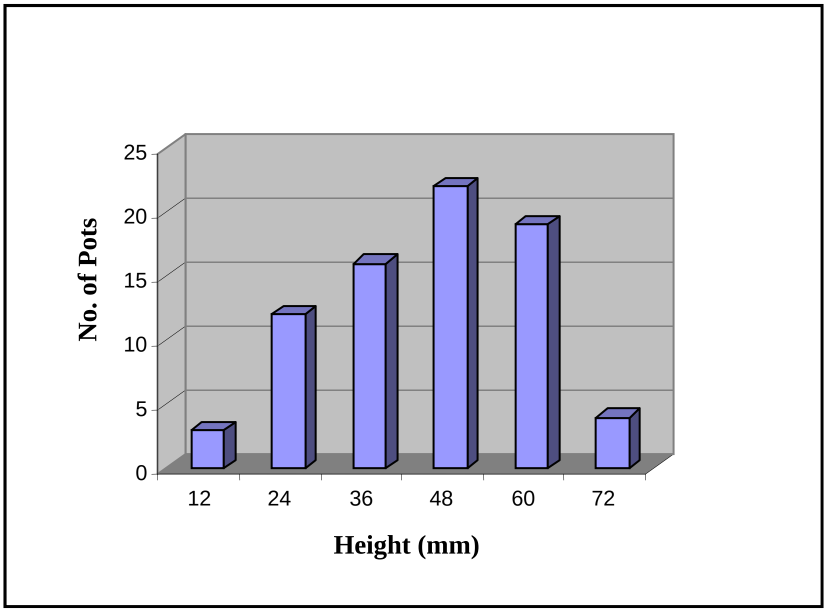

Figure 15. Histogram of the height of surviving Michaux's sumac plants at week 10.

The height analysis examined the linear rate of growth over time and found that the differences were significant (p=<0.0001, Table 5). The slopes were calculated to examine the change in growth rate for each soil type (Table 6).

Table 5. Fixed effect for Michaux's sumac height data in different soil media.

Effect	Num DF	Den DF	F Value	P Value
Week*Soil	11	344	9.78	<.0001

Num DF – Numerator degrees of freedom
Den DF – Denominator degrees of freedom

Table 6. Slope comparison of height data for Michaux's sumac in different soil media.

Soil Type	Intercept	Slope
50% Clay/50% Loam	-4.1169	6.3537
33% Sand/33% Loam/33% Clay	-1.3270	5.2561
EO 5	-3.6051	5.0917
EO 36	-4.1127	4.8568
100% Loam	-1.8484	4.4481
EO 33	-1.6768	4.1310
50% Loam/50% Sand	0.0467	4.1236
EO 16	-1.3854	3.1140
EO 25	-0.9985	2.5222
100% Sand	-1.7816	2.4573
100% Clay	-2.7112	2.1762
50% Clay/50% Sand	0.4269	1.8731

By calculating the slope, I compared the differences in the growth over the entire ten weeks rather than one week at a time (Figure 16). As with sprouting, 50% clay/50% loam was the best soil type. Although there was less sprouting in soils with 33% sand/33% loam/33% clay and in soil collected from EO 5 (loam), the plants that did sprout grew at a faster rate. For future greenhouse transplants, 50% clay/50% loam should be the soil medium.

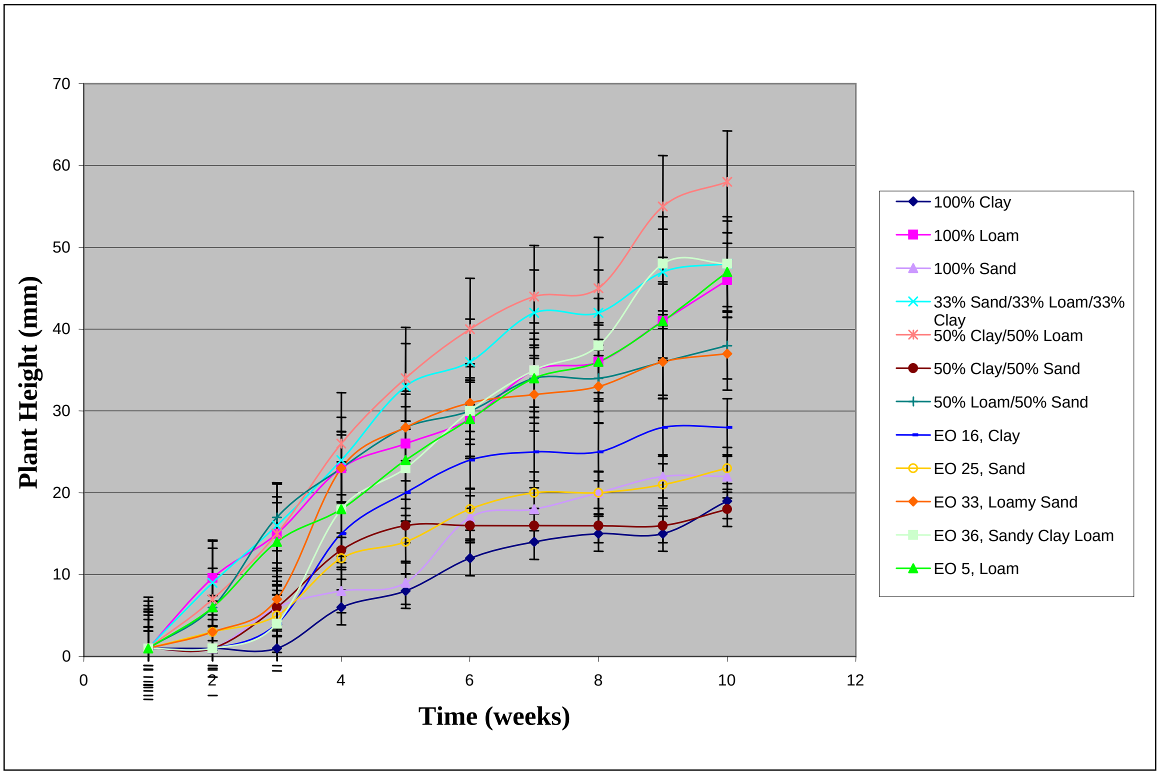

Figure 16. Plant height over time for Michaux's sumac in the greenhouse.

The length of the longest leaf analysis examined the linear rate of growth over time and found that the differences were significant (p=0.0012) (Table 7). The slopes were calculated to examine the change in the rate of growth for each soil type (Table 8).

Table 7. Fixed effect for Michaux's sumac length of longest leaf data in different soil media.

Effect	**Num DF**	**Den DF**	**F Value**	**P Value**
Week*Soil	11	372	2.88	0.0012

Num DF – Numerator degrees of freedom
Den DF – Denominator degrees of freedom

Table 8. Slope comparison of length of longest leaf data for Michaux's sumac in different soil media.

Soil Type	**Intercept**	**Slope**
EO 5	18.8537	13.5409
100% Loam	27.6099	13.5034
EO 36	1.4715	12.9113
50% Clay/50% Loam	46.9769	12.7568
33% Sand/33% Loam/33% Clay	77.8865	7.9874
100% Clay	-11.0257	6.7817
100% Sand	8.1166	6.6486
EO 25	14.6277	5.8184
50% Loam/50% Sand	69.2395	5.4483
EO 33	66.2674	3.1535
EO 16	55.8223	2.9704
50% Clay/50% Sand	63.7859	0.2254

If the native soil treatments are removed, the soil combinations with loam are still best. I believe this reveals that loam is an important soil component for Michaux's sumac to survive. Loam is also important for many other woody species, and is usually the preferred medium for forest nurseries (Pritchett and Fisher 1987).

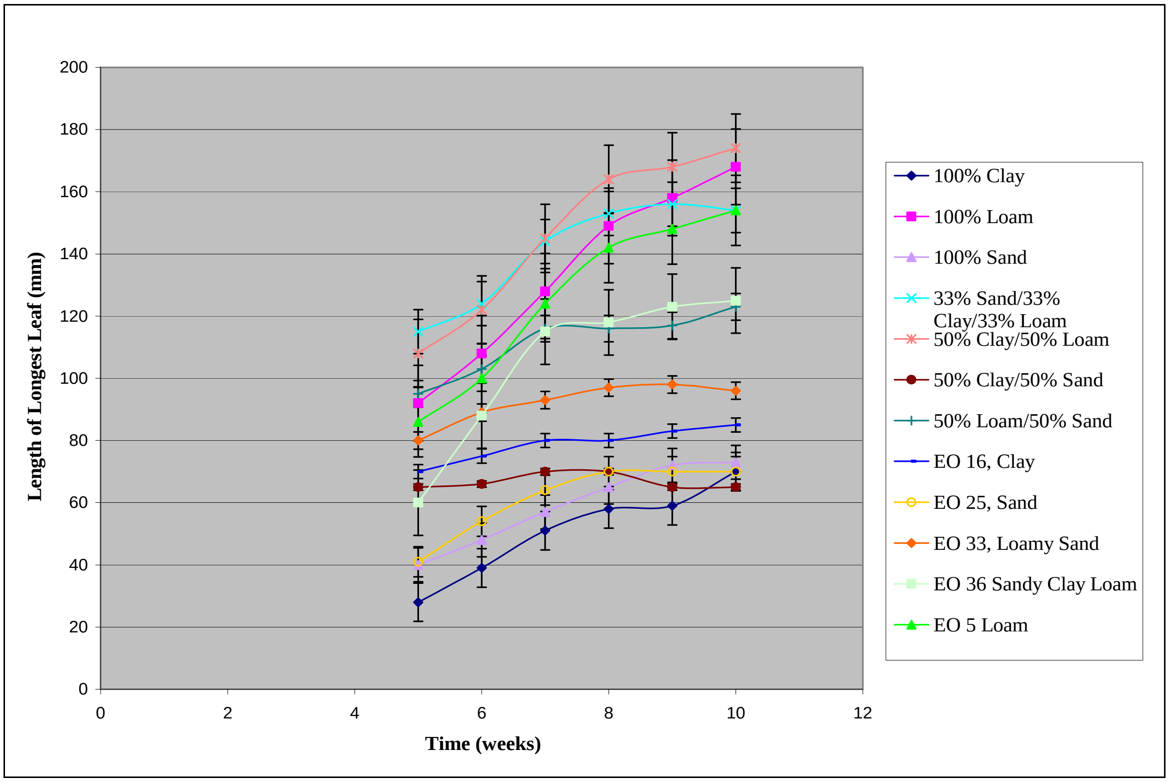

Figure 17. Average length of the longest leaf in the Michaux's sumac greenhouse experiment.

CONCLUSIONS

Conclusions drawn from part 1:

- More accurate and timely information on the status of Michaux's sumac is needed.
- Natural populations of Michaux's sumac in NC are declining.

Conclusions drawn from part 2:

- Soils are important in determining where Michaux's sumac survives, but not the sole limiting factor.
- Nutrient poor soils limit competition which could contribute to the current location of Michaux's sumac populations.

Conclusions drawn from part 3:

- The host soils of many Michaux's sumac populations are not necessarily the optimal soils.
- When transplanting Michaux's sumac the potting medium should be a mixture of 50% clay/50% loam.

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APPENDICES

Appendix 1: Soil nutrient analysis results for Michaux's sumac NC populations.

Site Rankings	# of plants	Canopy Cover	pH	Ca (kg/ha)	Mg (kg/ha)	P-I	K-I	Mn-AI	Zn-AI	Cu-I	S-I
EO 15 sub pop. 1	828	open	5	246	37	0	11	151	8	39	50
EO 51	758	open	5	294	78	0	5	28	19	20	18
EO 54	750	open	5.7	911	261	54	43	78	164	68	23
EO 15 sub pop. 5	540	open	5.1	294	47	10	12	189	77	37	33
EO 34 sub. pop. 1	500	open	5	187	25	0	7	169	5	29	29
EO 49	499	open	6.1	1440	97	0	12	638	9	20	14
EO 36	458	open	4.8	216	39	57	7	103	28	48	34
EO 43	271	open	5	300	44	0	7	67	0	31	54
EO 12	179	open	5.1	384	68	0	18	484	17	39	45
EO 27 sub. pop. 2	170	open	4.9	546	57	0	9	276	7	33	32
EO 55	157	open	4.2	168	41	44	14	52	42	51	24
EO 8	150	moderate	5	480	82	122	21	152	47	42	31
EO 34 sub. pop. 2	143	open	5.2	202	31	0	9	62	5	27	34
EO 13	128	closed	5.1	383	72	12	25	462	10	41	44
EO 58	114	open	5	292	26	0	9	153	19	21	24
EO 38	109	moderate	4.7	1152	26	0	6	292	1	24	47
EO 48	103	open	5	167	27	0	5	508	0	21	28
EO 44	90	open	4.8	184	46	0	35	378	0	24	117
EO 01	83	moderate	4.8	365	93	13	23	145	39	47	44
EO11 sub. pop. 4	79	moderate	4.7	190	34	0	5	268	0	24	31
EO11 sub. pop. 2	63	moderate	4.8	151	33	0	6	278	0	20	40
EO 52	59	open	7.3	8206	380	12	37	243	99	70	46
EO 27 sub. pop. 3	56	open	4.9	176	27	0	7	484	12	43	39
EO 33	55	open	5.1	158	31	0	8	106	23	139	31
EO 32	44	moderate	5.5	174	26	0	6	53	0	11	19
EO 30	43	moderate	4.9	203	38	0	15	109	7	41	79
EO 31	42	open	5	346	55	0	12	490	21	43	29
EO 35	38	moderate	4.9	139	28	0	13	721	2	37	67
EO 39	35	open	5.1	213	48	0	15	859	25	28	59
EO 45	26	open	5.4	384	64	0	11	429	0	21	27
EO 26	23	moderate	4.8	151	31	0	8	600	10	35	49
EO 25	19	moderate	4.9	1465	108	13	18	319	61	77	51

Appendix 1: Soil nutrient analysis results for Michaux's sumac NC populations (cont.).

Site Rankings	**# of plants**	**Canopy Cover**	**pH**	**Ca (kg/ha)**	**Mg (kg/ha)**	**P-I**	**K-I**	**Mn-AI**	**Zn-AI**	**Cu-I**	**S-I**
EO 47	18	open	4.6	180	33	1	9	51	24	32	35
EO 42	17	open	4.9	176	38	0	9	186	6	32	46
EO 27 sub. pop. 1	13	open	5.3	322	51	0	5	408	0	25	27
EO 16	10	open	4.9	381	116	0	38	56	16	25	124
EO 7	9	moderate	5.1	245	53	0	8	558	11	35	31
EO 19	6	moderate	5.5	1141	106	0	21	704	4	57	37
EO 28	5	closed	4.8	1944	39	0	6	398	0	36	55
EO 20	1	moderate	5.5	416	101	0	22	294	0	21	18
EO 37 sub. pop. 2	0	closed	6	1624	85	0	9	560	65	51	42
EO 05	0	open	6.2	3500	1660	0	29	414	43	109	20
EO 14	0	moderate	5	384	45	62	10	135	59	54	25
EO 6	0	*	4	125	25	61	6	40	35	9	46

* population eliminated because of development.

Appendix 2: Height growth data for Michaux's sumac greenhouse experiment.

		3/29/2006	4/5/2006	4/12/2006	4/20/2006	4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10
Pots	Soil Type	height	height	height	height	height	height	height	height	height	height
4	100%Clay	0	0	0	0	0	0	0	0	0	0
16	100%Clay	0	0	0	0	0	0	1	1	1	10
19	100%Clay	0	0	0	0	0	0	0	0	0	0
42	100%Clay	0	0	0	0	0	0	0	0	0	0
52	100%Clay	0	0	1	10	20	35	35	35	35	40
78	100%Clay	0	0	0	0	0	0	0	0	0	0
90	100%Clay	0	0	0	0	0	0	0	0	0	0
95	100%Clay	0	0	0	0	0	0	10	15	15	15
114	100%Clay	0	0	0	0	0	0	0	0	0	0
136	100%Clay	0	0	0	0	0	0	0	0	0	0
141	100%Clay	0	0	0	0	0	0	0	0	0	0
144	100%Clay	0	0	0	0	0	0	0	0	0	1
156	100%Clay	0	0	0	0	0	0	0	0	0	0
165	100%Clay	0	0	0	0	0	0	0	0	0	0
177	100%Clay	0	1	1	20	20	25	25	25	25	30
2	100%Loam	0	1	5	5	15	15	25	25	30	35
36	100%Loam	0	0	0	0	0	0	0	0	0	0
41	100%Loam	0	0	0	0	0	0	0	0	0	0
48	100%Loam	1	20	22	30	30	35	40	45	50	50
56	100%Loam	1	15	20	25	30	30	30	35	35	35
64	100%Loam	0	1	15	25	25	30	40	35	45	50
65	100%Loam	1	12	15	20	20	20	30	30	35	35
76	100%Loam	0	0	0	12	15	25	30	25	40	50
77	100%Loam	0	0	0	0	0	0	0	0	0	0
79	100%Loam	1	10	20	30	40	40	40	45	45	50
87	100%Loam	1	1	10	15	20	20	25	25	30	35

Appendix 2: Height growth data for Michaux's sumac greenhouse experiment (cont.).

		3/29/2006	4/5/2006	4/12/2006	4/20/2006	4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10
Pots	Soil Type	height	height	height	height	height	height	height	height	height	height
98	100%Loam	1	25	25	25	25	25	35	35	25	40
108	100%Loam	0	1	7	20	20	30	30	35	40	45
157	100%Loam	0	0	0	0	0	0	0	0	0	0
179	100%Loam	1	10	10	20	20	22	25	25	30	30
1	100%Sand	0	0	0	0	0	0	0	0	0	0
3	100%Sand	0	0	0	0	0	0	0	0	0	0
6	100%Sand	0	0	0	0	0	0	0	0	0	0
14	100%Sand	0	0	0	0	0	0	0	0	0	0
24	100%Sand	0	0	0	0	0	0	0	0	0	0
33	100%Sand	0	0	0	0	0	0	0	0	0	0
35	100%Sand	0	0	0	0	0	0	0	0	0	0
37	100%Sand	0	0	0	0	0	0	0	0	0	0
55	100%Sand	1	1	7	10	10	10	10	10	10	10
66	100%Sand	0	0	0	0	1	20	25	30	35	35
68	100%Sand	0	0	0	0	0	0	0	0	0	0
74	100%Sand	0	0	0	0	0	0	0	0	0	0
94	100%Sand	0	0	0	0	0	0	0	0	0	0
101	100%Sand	0	1	10	15	15	20	20	20	20	20
104	100%Sand	0	0	0	0	0	0	0	0	0	0
5	33%/33%/33%	0	1	10	25	25	30	40	40	40	45
17	33%/33%/33%	0	0	0	0	0	0	0	0	0	0
27	33%/33%/33%	1	10	20	25	30	30	35	35	40	40
121	33%/33%/33%	0	0	0	0	0	0	0	0	0	0
131	33%/33%/33%	0	0	0	0	0	0	0	0	0	0
138	33%/33%/33%	0	0	0	0	0	0	0	0	0	0
145	33%/33%/33%	0	0	0	0	0	0	0	0	0	0

Appendix 2: Height growth data for Michaux's sumac greenhouse experiment (cont.).

		3/29/2006	4/5/2006	4/12/2006	4/20/2006	4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10
Pots	Soil Type	height	height	height	height	height	height	height	height	height	height
146	33%/33%/33%	0	0	1	12	30	35	40	40	50	50
153	33%/33%/33%	0	0	0	0	0	0	0	0	0	0
155	33%/33%/33%	1	10	20	25	35	40	40	40	50	50
158	33%/33%/33%	0	15	20	30	40	45	50	50	55	55
162	33%/33%/33%	0	1	1	10	35	35	45	45	50	50
169	33%/33%/33%	1	25	30	30	35	40	50	50	55	55
173	33%/33%/33%	1	15	20	35	35	35	40	40	40	45
175	33%/33%/33%	1	12	20	25	30	30	40	40	40	40
92	50%Clay/50%Loam	0	0	0	0	0	0	0	0	0	0
93	50%Clay/50%Loam	0	1	10	25	30	40	45	45	50	65
125	50%Clay/50%Loam	0	1	15	25	25	40	40	45	50	55
133	50%Clay/50%Loam	0	0	1	1	20	25	25	30	40	45
143	50%Clay/50%Loam	0	0	10	25	40	40	50	50	55	60
100	50%Clay/50%Loam	0	0	0	0	0	0	0	0	0	0
140	50%Clay/50%Loam	1	12	15	25	30	30	40	40	40	50
149	50%Clay/50%Loam	0	0	0	0	0	0	0	0	0	0
176	50%Clay/50%Loam	1	1	10	30	30	30	40	40	40	45
178	50%Clay/50%Loam	0	1	7	25	35	40	45	45	55	55
180	50%Clay/50%Loam	0	0	1	20	35	40	40	40	60	70
81	50%Clay/50%Loam	1	15	30	30	40	45	50	45	50	55
172	50%Clay/50%Loam	0	1	20	35	40	50	50	55	60	70
11	50%Clay/50%Loam	0	0	0	0	0	0	0	0	0	0
53	50%Clay/50%Loam	1	40	40	50	50	60	60	60	60	65
113	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
134	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
88	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0

Appendix 2: Height growth data for Michaux's sumac greenhouse experiment (cont.).

		3/29/2006	4/5/2006	4/12/2006	4/20/2006	4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10
Pots	Soil Type	height	height	height	height	height	height	height	height	height	height
96	50%Clay/50%Sand	1	1	10	15	15	15	15	15	15	15
99	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
107	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
142	50%Clay/50%Sand	1	1	5	10	20	20	20	20	20	20
148	50%Clay/50%Sand	0	1	1	15	20	20	20	15	20	20
171	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
174	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
20	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
63	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
73	50%Clay/50%Sand	1	1	7	10	10	10	10	10	10	15
75	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
26	50%Clay/50%Sand	0	0	0	0	0	0	0	0	0	0
38	50%Loam/50%Sand	0	0	0	0	0	0	0	0	0	0
58	50%Loam/50%Sand	0	1	15	30	40	40	40	40	45	50
84	50%Loam/50%Sand	0	0	0	0	0	0	0	0	0	0
85	50%Loam/50%Sand	0	1	20	30	30	30	40	40	40	45
89	50%Loam/50%Sand	0	0	0	0	0	0	0	0	0	0
115	50%Loam/50%Sand	1	15	15	25	25	30	30	30	30	30
116	50%Loam/50%Sand	0	0	0	0	0	0	0	0	0	0
123	50%Loam/50%Sand	0	0	0	0	0	0	0	0	0	0
15	50%Loam/50%Sand	1	20	22	25	25	30	30	30	30	35
23	50%Loam/50%Sand	0	0	0	0	0	0	0	0	0	0
40	50%Loam/50%Sand	1	20	25	25	25	25	35	35	35	35
83	50%Loam/50%Sand	0	0	0	0	0	0	0	0	0	0
130	50%Loam/50%Sand	1	12	20	20	25	25	25	25	25	25
62	50%Loam/50%Sand	0	0	0	1	10	20	30	30	35	40

Appendix 2: Height growth data for Michaux's sumac greenhouse experiment (cont.).

		3/29/2006	4/5/2006	4/12/2006	4/20/2006	4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10
Pots	Soil Type	height	height	height	height	height	height	height	height	height	height
32	50%Loam/50%Sand	0	1	15	30	40	40	45	45	45	45
10	EO 16	1	1	7	15	20	25	25	25	25	25
12	EO 16	0	0	0	0	0	0	0	0	0	0
18	EO 16	0	0	0	0	0	0	0	0	0	0
50	EO 16	0	0	0	0	0	0	0	0	0	0
51	EO 16	0	0	0	0	0	0	0	0	0	0
61	EO 16	0	0	0	0	0	0	0	0	0	0
82	EO 16	0	0	0	0	0	0	0	0	0	0
97	EO 16	0	0	0	0	0	0	0	0	0	0
106	EO 16	0	0	0	0	0	0	0	0	0	0
126	EO 16	0	0	0	0	0	0	0	0	0	0
132	EO 16	0	0	0	0	0	0	0	0	0	0
160	EO 16	0	0	0	0	0	0	0	0	0	0
166	EO 16	0	0	1	15	20	22	25	25	30	30
8	EO 25	0	0	0	0	0	0	0	0	0	0
21	EO 25	0	0	1	10	12	20	20	20	20	20
28	EO 25	0	0	0	0	0	0	0	0	0	0
29	EO 25	1	1	7	12	20	20	20	20	20	20
46	EO 25	1	10	12	20	20	20	20	20	20	25
47	EO 25	1	12	10	10	8	15	20	20	20	20
54	EO 25	0	0	0	0	0	0	0	0	0	0
67	EO 25	0	0	0	0	1	15	15	15	20	20
69	EO 25	0	0	0	0	0	0	0	0	0	0
86	EO 25	0	0	0	0	0	0	0	0	0	0
91	EO 25	0	0	0	0	0	0	0	0	0	0
102	EO 25	0	1	5	15	15	15	20	20	20	20

Appendix 2: Height growth data for Michaux's sumac greenhouse experiment (cont.).

		3/29/2006	4/5/2006	4/12/2006	4/20/2006	4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10
Pots	Soil Type	height	height	height	height	height	height	height	height	height	height
112	EO 25	0	0	0	0	0	0	0	0	0	0
124	EO 25	0	0	0	0	0	0	0	0	0	0
127	EO 25	0	0	1	15	20	20	25	25	30	35
7	EO 33	0	0	1	15	15	30	35	35	40	40
25	EO 33	0	0	0	0	0	0	0	0	0	0
44	EO 33	0	0	0	0	0	0	0	0	0	0
49	EO 33	0	0	0	0	0	0	0	0	0	0
72	EO 33	0	0	1	20	35	35	35	35	40	40
80	EO 33	0	0	0	0	0	0	0	0	0	0
111	EO 33	0	0	0	0	0	0	0	0	0	0
119	EO 33	0	0	0	0	0	0	0	0	0	0
128	EO 33	0	1	15	30	35	40	40	40	45	45
129	EO 33	0	0	0	0	0	0	0	0	0	0
147	EO 33	0	0	0	0	0	0	0	0	0	0
152	EO 33	0	0	0	0	0	0	0	0	0	0
154	EO 33	1	15	12	20	20	20	20	20	20	20
163	EO 33	0	1	5	25	30	30	30	35	40	40
167	EO 33	0	1	5	25	30	30	30	30	30	35
9	EO 36	0	0	0	0	0	0	0	0	0	0
13	EO 36	0	0	0	0	0	0	0	0	0	0
30	EO 36	0	0	0	0	0	0	0	0	0	0
34	EO 36	0	0	0	0	0	0	0	0	0	0
39	EO 36	1	1	7	20	25	30	40	40	40	40
59	EO 36	0	0	0	0	0	0	0	0	0	0
60	EO 36	0	0	0	0	0	0	0	0	0	0
117	EO 36	0	0	0	0	0	0	0	0	0	0

Appendix 2: Height growth data for Michaux's sumac greenhouse experiment (cont.).

		3/29/2006	4/5/2006	4/12/2006	4/20/2006	4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10
Pots	Soil Type	height	height	height	height	height	height	height	height	height	height
120	EO 36	0	0	0	0	0	0	0	0	0	0
122	EO 36	0	0	0	0	0	0	0	0	0	0
137	EO 36	0	0	0	0	0	0	0	0	0	0
151	EO 36	0	0	0	0	0	0	0	0	0	0
164	EO 36	0	1	1	15	20	30	30	35	45	45
168	EO 36	0	0	0	0	0	0	0	0	0	0
170	EO 36	0	0	0	0	0	0	0	0	0	0
22	EO 5	0	0	0	0	0	0	0	0	0	0
31	EO 5	0	0	0	0	0	0	0	0	0	0
43	EO 5	0	1	20	25	30	35	40	40	40	50
57	EO 5	1	1	12	15	20	25	30	30	35	40
70	EO 5	0	0	0	0	0	0	0	0	0	0
71	EO 5	1	1	10	10	15	20	25	30	30	40
103	EO 5	1	20	20	25	30	40	40	40	50	55
105	EO 5	1	22	23	25	20	25	30	35	40	45
109	EO 5	0	0	0	0	0	0	0	0	0	0
110	EO 5	0	0	0	0	0	0	0	0	0	0
118	EO 5	0	0	0	0	0	0	0	0	0	0
135	EO 5	1	1	17	20	20	30	30	30	40	45
139	EO 5	0	1	10	25	30	30	40	35	45	50
150	EO 5	0	0	0	0	0	0	0	0	0	0
161	EO 5	0	0	0	1	25	30	35	40	45	50

Appendix 3: Length of longest leaf data for Michaux's sumac greenhouse experiment.

		4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk5	**wk6**	**wk7**	**wk8**	**wk9**	**wk10**
Plots	**Soil Type**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**
4	100%Clay	0	0	0	0	0	0
16	100%Clay	0	0	1	1	1	45
19	100%Clay	0	0	0	0	0	0
42	100%Clay	0	0	0	0	0	0
52	100%Clay	30	65	75	75	75	75
78	100%Clay	0	0	0	0	0	0
90	100%Clay	0	0	0	0	0	0
95	100%Clay	0	0	40	65	70	70
114	100%Clay	0	0	0	0	0	0
136	100%Clay	0	0	0	0	0	0
141	100%Clay	0	0	0	0	0	0
144	100%Clay	0	0	0	0	0	1
156	100%Clay	0	0	0	0	0	0
165	100%Clay	0	0	0	0	0	0
177	100%Clay	80	90	90	90	90	90
2	100%Loam	75	80	95	95	115	150
36	100%Loam	0	0	0	0	0	0
41	100%Loam	0	0	0	0	0	0
48	100%Loam	130	140	150	155	155	155
56	100%Loam	100	115	130	145	145	145
64	100%Loam	110	110	130	160	165	180
65	100%Loam	90	105	140	165	190	90
76	100%Loam	40	65	90	140	165	175
77	100%Loam	0	0	0	0	0	0
79	100%Loam	160	165	175	180	190	190
87	100%Loam	70	70	90	95	110	135
98	100%Loam	100	100	140	175	175	175
108	100%Loam	110	110	120	155	155	185
157	100%Loam	0	0	0	0	0	0
179	100%Loam	30	130	150	170	170	170
1	100%Sand	0	0	0	0	0	0
3	100%Sand	0	0	0	0	0	0
6	100%Sand	0	0	0	0	0	0
14	100%Sand	0	0	0	0	0	0
24	100%Sand	0	0	0	0	0	0
33	100%Sand	0	0	0	0	0	0
35	100%Sand	0	0	0	0	0	0
37	100%Sand	0	0	0	0	0	0
55	100%Sand	30	30	30	35	35	40
66	100%Sand	1	25	50	70	90	90
68	100%Sand	0	0	0	0	0	0
74	100%Sand	0	0	0	0	0	0
94	100%Sand	0	0	0	0	0	0

Appendix 3: Length of longest leaf data for Michaux's sumac greenhouse experiment (cont.).

		4/27/2006	5/3/2006	5/11/2006	5/18/2006	5/25/2006	6/1/2006
		wk5	wk6	wk7	wk8	wk9	wk10
Plots	Soil Type	Leaf length	Leaf length	Leaf length	Leaf length	Leaf length	Leaf length
101	100%Sand	90	90	90	90	90	90
104	100%Sand	0	0	0	0	0	0
5	33/33/33	110	85	120	125	135	135
17	33/33/33	0	0	0	0	0	0
27	33/33/33	120	130	150	150	150	150
121	33/33/33	0	0	0	0	0	0
131	33/33/33	0	0	0	0	0	0
138	33/33/33	0	0	0	0	0	0
145	33/33/33	0	0	0	0	0	0
146	33/33/33	55	75	115	140	140	140
153	33/33/33	0	0	0	0	0	0
155	33/33/33	140	150	160	165	165	165
158	33/33/33	145	150	175	175	175	160
162	33/33/33	65	75	110	130	140	145
169	33/33/33	130	170	175	175	175	175
173	33/33/33	160	160	165	170	170	170
175	33/33/33	110	120	130	150	150	150
92	50%C/L	0	0	0	0	0	0
93	50%C/L	120	133	150	170	175	175
125	50%C/L	95	110	130	150	160	160
133	50%C/L	20	35	75	100	115	145
143	50%C/L	100	115	140	170	175	175
100	50%C/L	0	0	0	0	0	0
140	50%C/L	160	170	180	185	190	185
149	50%C/L	0	0	0	0	0	0
176	50%C/L	125	140	160	170	170	175
178	50%C/L	100	110	150	180	180	180
180	50%C/L	60	80	120	170	180	200
81	50%C/L	145	155	170	175	175	155
172	50%C/L	130	150	170	180	180	180
11	50%C/L	0	0	0	0	0	0
53	50%C/L	130	145	150	150	150	150
113	50%C/S	0	0	0	0	0	0
134	50%C/S	0	0	0	0	0	0
88	50%C/S	0	0	0	0	0	0
96	50%C/S	70	70	70	70	70	70
99	50%C/S	0	0	0	0	0	0
107	50%C/S	0	0	0	0	0	0
142	50%C/S	70	75	85	85	85	85
148	50%C/S	65	65	65	65	65	65
171	50%C/S	0	0	0	0	0	0
174	50%C/S	0	0	0	0	0	0
20	50%C/S	0	0	0	0	0	0

Appendix 3: Length of longest leaf data for Michaux's sumac greenhouse experiment (cont.).

		4/27/2006	**5/3/2006**	**5/11/2006**	**5/18/2006**	**5/25/2006**	**6/1/2006**
		wk5	**wk6**	**wk7**	**wk8**	**wk9**	**wk10**
Plots	**Soil Type**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**
63	50%C/S	0	0	0	0	0	0
73	50%C/S	50	55	60	60	40	40
75	50%C/S	0	0	0	0	0	0
26	50%C/S	0	0	0	0	0	0
38	50%L/S	0	0	0	0	0	0
58	50%L/S	110	140	140	135	145	150
84	50%L/S	0	0	0	0	0	0
85	50%L/S	120	130	130	130	130	135
89	50%L/S	0	0	0	0	0	0
115	50%L/S	110	110	110	115	115	115
116	50%L/S	0	0	0	0	0	0
123	50%L/S	0	0	0	0	0	0
62	50%L/S	30	45	95	100	100	105
15	50%L/S	110	115	130	130	125	130
23	50%L/S	0	0	0	0	0	0
40	50%L/S	90	80	90	90	90	110
83	50%L/S	0	0	0	0	0	0
130	50%L/S	80	90	110	110	110	115
32	50%L/S	110	115	120	120	120	120
10	EO16	80	90	100	100	100	100
12	EO16	0	0	0	0	0	0
18	EO16	0	0	0	0	0	0
45	EO16	0	0	0	0	0	0
50	EO16	0	0	0	0	0	0
51	EO16	0	0	0	0	0	0
61	EO16	0	0	0	0	0	0
82	EO16	0	0	0	0	0	0
97	EO16	0	0	0	0	0	0
106	EO16	0	0	0	0	0	0
126	EO16	0	0	0	0	0	0
132	EO16	0	0	0	0	0	0
159	EO16	0	0	0	0	0	0
160	EO16	0	0	0	0	0	0
166	EO16	60	60	60	60	65	70
8	EO25	0	0	0	0	0	0
21	EO25	30	50	60	70	70	70
28	EO25	0	0	0	0	0	0
29	EO25	50	65	70	70	70	70
46	EO25	60	60	60	60	60	60
47	EO25	40	40	60	70	70	70
54	EO25	0	0	0	0	0	0
67	EO25	1	35	55	75	75	80
69	EO25	0	0	0	0	0	0

Appendix 3: Length of longest leaf data for Michaux's sumac greenhouse experiment (cont.).

		4/27/2006	**5/3/2006**	**5/11/2006**	**5/18/2006**	**5/25/2006**	**6/1/2006**
		wk5	**wk6**	**wk7**	**wk8**	**wk9**	**wk10**
Plots	**Soil Type**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**
86	EO25	0	0	0	0	0	0
91	EO25	0	0	0	0	0	0
102	EO25	50	60	70	70	70	60
112	EO25	0	0	0	0	0	0
124	EO25	0	0	0	0	0	0
127	EO25	55	65	70	75	75	80
7	EO33	80	85	100	100	100	100
25	EO33	0	0	0	0	0	0
44	EO33	0	0	0	0	0	0
49	EO33	0	0	0	0	0	0
72	EO33	50	85	85	85	85	85
80	EO33	0	0	0	0	0	0
111	EO33	0	0	0	0	0	0
119	EO33	0	0	0	0	0	0
128	EO33	100	100	100	105	105	95
129	EO33	0	0	0	0	0	0
147	EO33	0	0	0	0	0	0
152	EO33	0	0	0	0	0	0
154	EO33	100	105	105	105	110	110
163	EO33	75	90	90	95	95	95
167	EO33	75	70	80	90	90	90
9	EO36	0	0	0	0	0	0
13	EO36	0	0	0	0	0	0
30	EO36	0	0	0	0	0	0
34	EO36	0	0	0	0	0	0
39	EO36	80	105	120	120	120	120
59	EO36	0	0	0	0	0	0
60	EO36	0	0	0	0	0	0
117	EO36	0	0	0	0	0	0
120	EO36	0	0	0	0	0	0
122	EO36	0	0	0	0	0	0
137	EO36	0	0	0	0	0	0
151	EO36	0	0	0	0	0	0
164	EO36	40	70	110	115	125	130
168	EO36	0	0	0	0	0	0
170	EO36	0	0	0	0	0	0
22	EO5	0	0	0	0	0	0
31	EO5	0	0	0	0	0	0
43	EO5	90	105	140	155	155	160
57	EO5	80	0	125	150	150	150
70	EO5	0	0	0	0	0	0
71	EO5	50	65	120	135	140	145
103	EO5	120	125	130	135	150	150

Appendix 3: Length of longest leaf data for Michaux's sumac greenhouse experiment (cont.).

		4/27/2006	**5/3/2006**	**5/11/2006**	**5/18/2006**	**5/25/2006**	**6/1/2006**
		wk5	**wk6**	**wk7**	**wk8**	**wk9**	**wk10**
Plots	**Soil Type**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**	**Leaf length**
105	EO5	90	100	105	150	150	150
109	EO5	0	0	0	0	0	0
110	EO5	0	0	0	0	0	0
118	EO5	0	0	0	0	0	0
135	EO5	100	105	130	145	16	160
139	EO5	120	155	160	165	175	175
150	EO5	0	0	0	0	0	0
161	EO5	40	50	85	100	110	140

Appendix 4. Michaux's sumac populations, locations, observations, and plant counts.

Sites	Location	2006 # of plants	1st Obs.	2nd Obs.	3rd Obs.	4th Obs.	5th Obs.	6th Obs.	7th Obs.	8th Obs.
EO 01	Franklin County Roadside	83	1980 - 100+p	1990 - 523p	1991 - 100+p	2004 - 8p	2005 - 0p			
EO 05	Davie County Roadside	0	1987 - 30p	1989 - 5p	1991 - 5p	1993 - 8p	1998 - 40p	2000 - 33p	2001 - 59p	2002 - 28p
EO 6	Antioch field	0	1981 - 10p	1987 - 0p	1990 - 21p	1991 - 300p	2003 - 0p			
EO 7	Sandhills Game Lands	9	1990 - 400p	1998 - 81p						
EO 8	Antioch (beside farmland)	150	1987 - 300p	1988 - 500p	1990 - 500p	2003 - 305p				
EO 9	Red Springs roadside	0	1981 - 1+p	1987 - 100+p	1988 - 150p	1990 - 64p				
EO 11 sp's	Sandhills Game Lands	142	1981 - 1+p	1989 - 53p	1990 - 100p	1994 - 113p	2003 - 12p			
EO 12	Sandhills Game Lands	179	1981 - 350p	1990 - 1000p	1994 - 217p	2003 - 300p				
EO 13	Sandhills Game Lands	128	1990 - 126p	1998 - 43p						
EO 14	Oak Ridge Farm Rd	0	1986 - 1+	1990 - 2						
EO 15 sp 1	Camp McCall Airfield	828	1995 - 100+p	1999 - 150+p						
EO 15 sp 5	Camp McCall Airfield	540	1995 - 333p	1999 - 300+p						
EO 16	Wake County Roadside	10	1987 - 280p	1990 - 300p	1992 - 256p	1999 - 42p	2002 - 23p	2004 - 46p	2005 - 30p	2005 - 19p
EO 19	Fort Bragg	6	1982 - 1+p	1986 - 0p	1988 - 25p	1990 - 22p	1992 - 10p	1995 - 20p	1998 - 17p	
EO 20	Sandhills Game Lands	1	1988 - 50p	1990 - 300p	1997 - 40p					
EO 25	Moore County Roadside	19	1990 - 17p	1994 - 9p	1997 - 23p	1991 - 23p	1998 - 80p			
EO 26	Sandhills Game Lands	23	1990 - 1000p	1991 - 700p						
EO 27 sp 1	Sandhills Game Lands	13	1998 - 13p							
EO 27 sp 2	Sandhills Game Lands	170	1998 - 122p							
EO 27 sp 3	Sandhills Game Lands	56	1998 - 75p							
EO 28	Sandhills Game Lands	5	1991 - 135p	1994 - 103p	2003 - 3p					
EO 30	Fort Bragg	43	1993 - 52p	1998 - 40+						
EO 31	Fort Bragg	42	1991 - 2p	1992 - 46p	1995 - 50p	1999 - 66p				
EO 32 sp's	Fort Bragg	44	1992 - 200+p	1995 - 410p	1998 - 50p					

sp-- sub-population   sp's-- indistinguishable sub-populations so numbers totaled   p-- plants

Appendix 4. Michaux's sumac populations, locations, observations, and plant counts (cont.).

Sites	Location	2006 # of plants	1st Obs.	2nd Obs.	3rd Obs.	4th Obs.	5th Obs.	6th Obs.	7th Obs.	8th Obs.
EO 33 sp's	Fort Bragg	55	1992 - 115p	1993 - 115+p	1998 - 250+p					
EO 34 sp 1	Fort Bragg	500	1993 - 100+p	1998 - 300+p						
EO 34 sp 2	Fort Bragg	143	1993 - 20+p	1998 - 75+p						
EO 35	Sandhills Game Lands	38	1992 - 65p	1994 - 70p	2003 - 4p					
EO 36	Drowning Creek (roadside)	458	1992 - 140p	1996 - 403p	2005 - 419p					
EO 37 sp 2	Sandhills Game Lands	0	1994 - 47p	2003 - 1p						
EO 38	Sandhills Game Lands	109	1994 - 7p	1995 - 50p	1998 - 10p	2003 - 0p				
EO 39	Sandhills Game Lands	35	1994 - 42p	1998 - 1p	2003 - 9p					
EO 42	Fort Bragg	17	1997 - 16p							
EO 43	Sandhills Game Lands	271	1998 - 57p							
EO 44	Sandhills Game Lands	90	1998 - 50p	2004 - 30+p						
EO 45	Sandhills Game Lands	26	1998 - 3p							
EO 47	Sandhills Game Lands	18	1998 - 38p							
EO 48	Sandhills Game Lands	103	1997 - 75p							
EO 49	Sandhills Game Lands	499	1997 - 50+p	1998 - 75p						
EO 51	Camp McCall Training Field	758	1999 - 300+p							
EO 52	Camp McCall Training Field	59	1999 - 7p							
EO 54	Marston Post Office (roadside)	750	2004 - 500+p							
EO 55	Hoffman (roadside)	157	2004 - 65p							
EO 58	Sandhills Game Lands	114	2004 - 100p	2005 - 50+p						

sp-- sub-population sp's-- indistinguishable sub-populations so numbers totaled p-- plants

Appendix 5. Weather data for days that Michaux's sumac was outside.

Date	Avg. Daily Temp (F)	Precipitation (in)
5/1/2006	56.2	0.00
5/2/2006	61.2	0.00
5/3/2006	65.6	0.00
5/4/2006	67.1	0.00
5/5/2006	70.3	0.00
5/6/2006	70.6	0.00
5/7/2006	58.9	0.04
5/8/2006	51.8	0.73
5/9/2006	56.4	0.01
5/10/2006	52.4	0.00
5/11/2006	68.9	0.04
5/12/2006	60.9	0.00
5/13/2006	61.4	0.00
5/14/2006	63.2	0.01
5/15/2006	59.8	0.21
5/16/2006	60.4	0.02
5/17/2006	60.7	0.00
5/18/2006	62.7	0.20
5/19/2006	60.5	0.02
5/20/2006	65.5	0.02
5/21/2006	71.3	0.00
5/22/2006	67.8	0.00
5/23/2006	62.7	0.00
5/24/2006	63.2	0.00
5/25/2006	73.5	0.00
5/26/2006	77.6	0.00
5/27/2006	76.0	0.07
5/28/2006	75.1	0.00
5/29/2006	76.0	0.00
5/30/2006	77.0	0.00
5/31/2006	78.0	0.21
6/1/2006	77.4	0.00
6/2/2006	78.0	0.85
6/3/2006	72.7	0.55
6/4/2006	69.3	0.00
6/5/2006	65.9	0.13
6/6/2006	64.4	0.01
6/7/2006	68.4	0.09
6/8/2006	72.1	0.00
6/9/2006	70.9	0.19
6/10/2006	74.0	0.00
6/11/2006	72.4	0.59
6/12/2006	71.6	0.27
6/13/2006	68.2	0.08
6/14/2006	67.2	0.54
6/15/2006	69.9	5.11
6/16/2006	72.3	0.00
6/17/2006	75.1	0.00
6/18/2006	75.4	0.00
6/19/2006	76.1	0.00
6/20/2006	79.6	0.00
6/21/2006	80.0	0.00
6/22/2006	79.5	0.00
6/23/2006	79.9	0.38
6/24/2006	76.0	0.16
6/25/2006	75.8	0.76
6/26/2006	75.1	0.16
6/27/2006	75.8	0.57
6/28/2006	77.9	0.01
6/29/2006	78.9	0.00
6/30/2006	75.4	0.00
7/1/2006	75.1	0.00
7/2/2006	80.3	0.00
7/3/2006	82.8	0.00
7/4/2006	83.4	0.00
7/5/2006	82.7	0.00
7/6/2006	73.4	0.75
7/7/2006	70.0	0.32
7/8/2006	69.6	0.00
7/9/2006	72.5	0.00
7/10/2006	76.0	0.00
7/11/2006	80.2	0.00
7/12/2006	81.6	0.00
7/13/2006	83.4	0.00
7/14/2006	82.1	0.22
7/15/2006	81.9	0.00
7/16/2006	82.5	0.00
7/17/2006	80.5	0.00
7/18/2006	82.7	0.00
7/19/2006	80.7	0.03
7/20/2006	78.5	0.00
7/21/2006	80.8	0.00
7/22/2006	81.8	0.05
7/23/2006	76.3	0.01
7/24/2006	75.9	0.29
7/25/2006	76.5	0.55
7/26/2006	77.7	1.06
7/27/2006	80.9	0.00
7/28/2006	81.5	0.01
7/29/2006	82.5	0.00