Mineral Ion and Water Concentrations in Woody Twigs of Deer Browse Species

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Submitted

by

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

As a non-migrating animal, the white tailed deer (*Odocoileus virginianus*) requires a continuous food supply during the winter months. The twigs of shrubs and small trees are an important component of the deer's diet. Of the many species available as browse, deer prefer some to others, and a subjective categorization of browse preference has been presented by Krefting, Hansen, and Hunt (1960) for the common Minnesota species. This classification is reproduced in Appendix A with species grouped according to a simple high, medium, or low preference.

While the fact that some species are browsed more heavily than others is well understood, the reasons for varying preference and the nutritive value of different species are not so clear. A great deal of work has been conducted to determine the nutrient content of crop species (Gerloff, Moore, and Curtis, 1964), but as Billings pointed out in 1957: "there are all too few mineral nutrition studies on wild plants of any kind,". This situation has changed somewhat since 1957, but many questions remain unanswered in the field of plant nutrition in natural environments. The questions concerning the nutritive value of deer browse are among these and would be benefited by more extensive studies of plant mineral concentrations.

With the above comments in mind, a study was undertaken to determine the mineral ion and moisture content of the first and second year twigs of some of the species included in Appendix A.

It is emphasized that the study was not conducted in an effort to determine reasons for deer preference (a measure of carbohydrate content might have been more appropriate) but to report mineral content. A major objective of the study was to determine, quite simply, if different species have significantly more (or less) mineral ions in their tissues than do others. Such information would aid not only wildlife managers, but also ecologists interested in the role plants play in the cycling of nutrients in natural environments.

STUDY AREA

The amount of nutrients taken up by a plant varies depending upon a number of factors including: amounts available in the soil, growth rates, vigor of plants, and species. Concentrations of given nutrients also vary depending upon total supply of all nutrients as well as the factors mentioned above. Coats (1967) summarizes the problems associated with foliar analysis. In order to test species' effect upon concentration, it is necessary to hold as many of the other factors as is possible constant. For this study, then, it was desired that all the individuals sampled occur within the same stand and that the stand be as uniform as possible. Because individual species have specific moisture, nutrient, heat, and light requirements (or tolerance), it is difficult to find a broad range of species in a given stand. This is especially true for the tree and shrub species.

At the outset of the study, a number of stands in the Itasca State Park area of Minnesota were surveyed. Criteria for selecting an area included; a uniform topography and soil, fairly dense and uniform overstory vegetation, and a high occurrence of species listed in Appendix A. The area selected is a mixed red pine (*Pinus resinosa* Ait.)-white pine (*Pinus strobus* L.) stand on the Park's north boundary road opposite the forestry headquarters. The stand occupies the site of an old pasture which reseeded naturally about 62 years ago. (Miller, 1968). Sampling of ten red pine and ten white pine (dominant and codominant trees) showed the red pine to have an average d.b.h. of 10.8 inches and height of 73.4 feet while the white pine averaged 12.4 inches d.b.h. and 74.6 feet in height. Two Bitterlick plots within the immediate area sampled indicate that the overstory is quite dense with 210 sq. ft. of basal area per acre evenly divided between red and white pine. The overstory is uniform with only an occasional bur oak (*Quercus macrocarpa* Michx.) or paper birch (*Betula papyrifera* Marsh.) interrupting it. The understory is dense, and there is a broad range of species represented in the vegetation (Appendix B). Synecological coordinates (see Bakuzis, 1959) for the stand are: 2.22 for moisture, 2.98 for nutrients, 2.80 for heat, and 2.98 for light. The nutrient value is quite high compared to other red pine-white pine stands which have been sampled within the Park (Kurmis, 1969), and this probably is a reflection of the pasture conditions once occupying the site. Although the soil is a typical, well drained Marquette loamy sand and podzolized, the influence of grass occupying the site some 60 years ago may account for the higher fertility reflected by the vegetation. The topography is nearly level, and this also probably accounts for part of the high fertility as it is likely that few of the nutrients have been lost to surface runoff.

METHODS AND PROCEDURE

Once a suitable area had been located, plants to be sampled were selected. Of the species in Appendix A, thirteen (six high preference, two medium preference, and five low preference) were found to be represented well enough to be included in the sampling. These species are: high preference- gray dogwood (Cornus racemosa Lam.), round leafed dogwood (Cornus rugosa Lam.), green ash (Fraxinus pennsylvanica Marsh.), choke cherry (Prunus virginiana L., bur oak, and arrow-wood (Viburnum Rafinesquianum Schult.); medium preference- paper birch and red oak (Quercus rubra L.); low preference- American hazel (Corylus americana Walt.), beaked hazel (Corylus cornuta Marsh.), hawthorn (Crataegus punctata Jacq.), ironwood (Ostrya virginiana (Mill.) K. Kock), and quacking aspen (Populus tremuloides Michx.). Three individuals of each of the above species were identified. They were visually determined to be vigorous and free from disease. An effort was made to select individuals four to six feet in height although the bur oak and ironwood samples were as much as twelve feet high. A dirt road borders the stand, but all individuals sampled were located at least three chains (198 feet) from the road in an effort to avoid dust contamination. The nutrient content of leaves and twigs varies at different times of the year, and variations are especially marked during the time when plants are actively photosynthesizing (Short, Dietz, and Remmenga, 1966). For this reason, sampling was delayed until mid-October when all the leaves of deciduous species have fallen in the Itasca area. Sampling was conducted between eight A. M. and five P. M. Twigs were dry at the time of sampling (no precipitation had occurred in the previous 24 hours), and rubber gloves were worn and stainless steel clippers used when separating first and second year twigs from the plants. Generally, four to five grams (wet weight) of twigs were removed and placed in brown paper bags. Through the above procedures, contamination was avoided. Similar care was taken throughout the analysis in an attempt to reduce the likelihood of the samples being contaminated. Upon returning from the field, buds were removed from the twigs and discarded, first year twigs were separated from second year twigs, and wet weights were recorded for each sample. Seventy-eight samples resulted with 39 each of first and second year twigs.

Samples were refrigerated, transported to St. Paul, and dried within 24 hours of the time of harvest. After 24 hours of drying at 103^{o} C., oven dry weights were recorded and moisture percentages determined. Each sample was ground in a Willey Mill (20 mesh stainless steel screen), and one gram of the resulting ground material was dry ashed at 525^{o} C. for four hours. The ash was then placed in solution with five mls. 0.5 percent lithium and 15 percent hydrochloric acid in distilled water. Samples were analysed for the following mineral elements with a Jarrell-Ashe emission spectrograph: phosphorus, potassium, calcium, strontium, sodium, iron, magnesium, zinc, copper, molybdenum, manganese, and boron.

Individuals sampled occurred roughly within a 100'x100'x100' equalateral triangle, with the peak pointing north and the base running east-west. The bulk of the individuals occurred in the southern portion of the triangle. At approximately each corner of the triangle a soil pit was dug and about 100 grams each of the A_1 and A_2 horizons were removed. These samples are labeled by location- either NC (north central), SW (southwest), or SE (southeast), and horizon- A_1 or A_2. They were analysed for exchangeable calcium, magnesium, potassium, and hydrogen, available phosphorus, and total nitrogen by Robert Munter, Research Fellow at the University of Minnesota's Soil Science Department.

RESULTS AND DISCUSSION

A computation of average synecological coordinate values for browse preference classes (using species in Appendix A) is presented in Table 1.

Preference Class	Average Synecological Coordinate			
	Moisture	Nutrients	Heat	Light
High	2.72	2.91	3.09	2.73
Medium	1.64	2.38	2.69	3.92
Low	1.70	2.60	2.70	3.20

Table 1. Synecological coordinate values for preference groups.

The high preference class has generally higher moisture, nutrient, and heat values and a lower light value than the other two classes. Such values would indicate that the species in the class would generally be found in semi-climax to climax hardwood vegetation (i. e. maple-basswood forests) rather than in vegetation indicative of earlier stages in plant succession (pine or aspen forests). Interestingly enough, the deer population in Minnesota is favored by the open type of vegetation resulting from land clearing and characterized by species intolerant to shade and capable of surviving low nutrient-low moisture conditions. An obvious explanation for this apparent contradiction is that, although high preference species tend to occurr in climax forests, the productivity of these forests is low at the level at which deer feed (stands tend to have poorly developed understories).

The results of the analysis conducted in this study give little indication that high preference species are also high in moisture or nutrient content, however. Mean mineral and moisture concentration values for the three individuals of each species are presented in Appendix D. Because one of the elements (preference class) in the study is nonparametric, it is not possible to statistically test for correlations between preference and concentration. Similarly, there are no nonparametric tests which could adequately test the relationships. The values, ranked from one extreme to the other, could be tested for randomness, but this would only tell whether or not browse preference classes are randomly distributed and would allow no statement concerning the reasons (if a nonrandom situation existed) for such an occurrence. Visual check of the data presented in Appendix C shows a slight indication of inverse relationships between browse preference and concentration for several of the elements (phosphorus, calcium, magnesium, iron, and zinc). These relationships are tenuous, however.

While little can be said of the relationships between browse preference and concentration of individual nutrients, this is not the only important factor to be considered. As mentioned earlier, the interaction of nutrients is also important. Working in the Huntington Wildlife Forest in New York, Bailey (1967) reported that eleven of twenty species browsed by deer had phosphorus concentrations of less than 0.16 percent. He reported that only four of the twenty species had calcium/phosphorus ratios of less than 3.0 and most heavily browsed species had ratios of 5.0 or greater. He concluded that his data suggested a phosphorus deficiency in deer browse although he stated that increased mortality could not be related to these apparent deficiencies. It is well known that in soils, high calcium values limit the availability of phosphorus to plant nutrition (Buckman and Brady, 1965). Calcium/phosphorus ratios of the data presented in this study are presented in Table 2.

	Ca/P	
High Preference	1st year twigs	2nd year twigs
Cornus racemosa	7.35	8.43
Cornus rugosa	8.60	8.49
Fraxinus pennsylvanica	4.55	4.72
Prunus virginiana	3.89	4.78
Quercus macrocarpa	8.64	10.27
Viburnum rafinesquianum	6.21	6.68
Medium Preference		
Betula papyrifera	2.26	3.80
Quercus rubra	7.17	6.21
Low Preference		
Corylus americana	6.11	8.14
Corylus cornuta	7.25	8.67
Crataegus punctata	8.12	10.20
Ostrya virginiana	8.45	9.57
Populus tremuloides	5.74	7.28

Table 2. Calcium/phosphorus ratios for first and second year twigs.

As in the New York study, few phosphorus concentrations (Appendix D) for the first year twigs are greater than 0.16 percent, and only one Ca/P ratio is less than 3.0 (Betula papyrifera). Only two ratios (Fraxinus pennsylvanica and Prunus virginiana) are less than 5.0. Concentrations are even less (and ratios greater) for second year twigs. Phosphorus levels in the soil are comparatively high (Munter, 1969), but calcium levels are also high (due probably to the fact that the till in the Itasca area is thought to have originated in Manitoba where large amounts of calcareous sedimentary deposits existed prior to Pleistocene glaciation). It is possible, then, that high soil calcium levels are restricting phosphorus uptake.

As mentioned in the introduction, the values reported in this study are of interest even without respect to deer browse preference if just inter-species relationships are considered. To validly compare species, however, the soils in the sampling area should be homogeneous. Results of the soil chemical analysis (Appendix C) indicate that, while samples from sites SE and SW are somewhat similar, the samples from NC are lower in fertility. This difference, in less than 100 feet, is not unusual for the Itasca region where soils are extremely heterogeneous. Bur oak was the only species concentrated in the area of the NC site and perhaps use of its values are not valid. Values for bur oak are presented but the above point should be kept in mind in comparing its values with others.

From the previous discussion, it appears that first year twigs generally have higher concentrations of moisture and elements than do second year twigs. A paired t test was conducted to determine the significance of these differences, and the results of this test are contained in Table 3. Because the twelve factors tested are independent, it is possible to compute an error rate per experiment for the data presented in Table 3. To have an error rate per experiment (α') equal to 0.05, an α=0.005 was used ($t_{1-\alpha;1,38}$= 2.97 based on the relation: $\alpha=1-(1-\alpha')^{1/12}$(Gerrard, 1969).

Factor		1st year twig	2nd year twig	t
Phosphorus	(percent)	0.171600	0.130453	11.22*
Potassium	(percent)	0.617204	0.441440	8.79*
Calcium	(percent)	1.099515	0.973552	5.31*
Strontium	(ppm)	37.843369	34.493195	3.80*
Iron	(ppm)	57.705811	61.274094	1.09
Magnesium	(percent)	0.146125	0.107830	10.79*
Zinc	(ppm)	59.687500	53.637416	2.54
Copper	(ppm)	19.281006	18.331131	0.31
Molybdenum	(ppm)	0.501457	0.426397	4.84*
Manganese	(ppm)	178.105255	128.698807	5.32*
Boron	(ppm)	21.364395	18.569992	6.15*
Water	(percent)	44.8717	42.6410	5.56*

* Significant at α=0.005.

Table 3. Mean concentration of moisture and elements in first and second year twigs from all species.

At this time, it should be pointed out that sodium concentrations are not included in this report as only 18 of 78 samples showed values high enough to be detected. Also, the manganese averages for bur oak, arrow wood, and American and beaked hazel should be higher as some samples from these species had values in excess of 350 ppm while averages were computed using 350 ppm for the samples.

Table 3 shows that several factors have significantly greater concentrations in first year twigs compared to second year twigs. This is probably a reflection of the greater amounts of meristematic tissue present in the newly formed twigs. Differences do not, however, appear to reflect the varying mobility of mineral ions in plant tissues. All of the elements generally reported (Meyer, Anderson, and Bohning, 1964) to be mobile in plant tissues (phosphorus, potassium, and magnesium) show significant increases in first year twigs but so also do the immobile elements: calcium, manganese, and boron. Only the immobile iron shows higher values in second year twigs. Interestingly, the above authors specifically state that calcium is present in greater concentrations in older tissues, while the present study would appear to contradict this.

Duncan's Multiple Range tests (Steele and Torrie, 1960) were used to determine the significance between species differences in minerals and moisture content of first and second year twigs. The results of these tests are found in Appendix D and are largely self-explanatory. Significant differences are found in each of the tests. The importance of the ability of different species to concentrate different amounts of elements and water under the same soil conditions is discussed in Patterson, 1969.

SUMMARY

Analysis of the first and second year twigs of several tree and shrub species of varying preference as deer browse gave the following results:

1. There appears to be little relationship between mineral ion or water concentration in twigs and deer browse preference.
2. The data appears to indicate that all but one of the thirteen species tested are low in phosphorus if the principles set forth

in Bailey's 1967 New York study are applicable to Minnesota.

3. Phosphorus, magnesium, potassium, calcium, manganese, boron, and molybdenum concentrations are significantly greater in first year twigs compared to second year twigs. Increases in first year twigs show little relationship to nutrient mobility within plants, however. Concentrations of calcium (which is highly immobile) is especially contradictory to published reports.

4. Different species show significant differences in the amounts of elements and water that they concentrate.

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APPENDIX A

Deer Browse Preference Classes

High Preference

Amelanchier spp.
Cornus alternifolia L. F.
Cornus racemosa Lam.
Cornus rugosa Lam.
Cornus stolonifera Mich.
Fraxinus pennsylvanica Marsh.
Prunus serotina Ehrh.
Prunus virginiana L.
Quercus macrocarpa Michx.
Viburnum Rafinesquianum Shultes
Viburnum trilobum Marsh.

Medium Preference

Betula papyrifera Marsh.
Lonicera dioica L.
Lonicera hirsuta Eat.
Pinus banksiana Lam.
Pinus strobus L.
Prunus pennsylvanica L. F.
Quercus rubra L.
Rhus radicans L.
Rosa blanda Ait.
Salix Bebbiana Sarg.
Salix humilis Marsh.
Ulmus americana L.
Vaccinium angustifolium Ait.

Low Preference

Corylus americana Walt.
Corylus cornuta Marsh.
Crataegus spp.
Diervilla Lonicera Mill.
Ostrya virginiana (Mill.) K. Kock
Pinus resinosa Ait.
Populus grandidentata Michx.
Populus tremuloides Michx.
Rubus idaeus L. var. *strigosis* (Michx.) Maxim
Symphoricarpos albus (L.) Blake

APPENDIX B

Plant List

Species	Coordinate Value MNHL
Abies balsamea (L.) Mill.	4212
Acer rubrum L.	2233
Acer saccharum Marsh.	3531
Actaea rubra (Ait.) Willd.	3321
Amelanchier laevis Wie.	3343
Amphicarpa bracteata (L.) Fern.	3243
Anemone quinquefolia L.	4334
Aralia nudicaulis L.	2223
Aralia racemosa L.	3541
Asarum canadense L.	4531
Aster ciliolatus Lindl.	2224
Aster laevis L.	1235
Aster macrophyllus L.	2223
Athyrium Felix femina L.	3321
Betula papyrifera Marsh.	3225
Bromus tectorum L.	2333
Carex spp.	4234
Clintonia borealis (Ait.) Raf.	3212
Cornus alternifolia L. F.	2541
Cornus canadensis L.	3212
Cornus racemosa Lam.	1443
Cornus rugosa Lam.	2332
Corylus americana Walt.	1235
Corylus cornuta Marsh.	2123
Crataegus punctata Jacq.	3544
Diervilla Lonicera Mill.	1223
Fragaria virginiana Duchesne	2224
Fraxinus pennsylvanica Marsh.	3544
Galium tectorum Michx.	3221
Hepatica americana (DC.) Ker	1332
Lathyrus venosus Muhl.	1225
Lonicera canadensis Bartr.	3221
Maianthemum canadense Desf.	1224
Osmorhiza claytonia (Michx.) C. B. Clarke	3531
Osmunda Claytonia L.	2552
Ostraya virginiana (Mill.) K. Kock	2541
Petasites palmatus (Ait.) Gray	4231
Pinus resinosa Ait.	1224
Pinus strobus L.	2223
Polygonatum pubescens (Willd.) Pursh	3542
Populus tremuloides Michx.	2224
Prunus pennsylvanica L. F.	1235
Prunus serotina Ehrh.	2343
Prunus virginiana L.	2334
Pteridium aquilinum L.	1224

<u>Quercus macrocarpa</u> Michx.	1343
<u>Quercus rubra</u> L.	1433
<u>Rhus radicans</u> L.	1334
<u>Rosa blanda</u> Ait.	1225
<u>Rubus idaeus</u> L. var. <u>strigosis</u> (Michx.) Maxim	3223
<u>Salix humilis</u> Marsh.	1234
<u>Smilacina stellata</u> (L.) Desf.	2543
<u>Smilax herbacia</u> L.	2542
<u>Symphoricarpos albus</u> (L.) Blake	2435
<u>Thalictrum dioicum</u> L.	2333
<u>Uvularia grandiflora</u> Sm.	2541
<u>Ulmus americana</u> L.	3542
<u>Vaccinium angustifolium</u> Ait.	1115
<u>Viburnum Rafinesquianum</u> Schultes	2233
<u>Viburnum trilobum</u> Marsh.	3333

APPENDIX C

Soil Chemical Analysis

Site	Horizon	Sample	Calcium ppm	Magnesium ppm	Potassium ppm	Hydrogen meg/100g	Phosphorus ppm	Nitrogen %
NC	A_1	1	1824	178.2	88	4.2	52	0.188
		2	2006	197.6	88	4.2	53	
	A_2	1	564	73.0	42	2.0	40	0.024
		2	612	77.6	44	2.3	40	
SE	A_1	1	2628	230.8	109	2.3	38	0.228
		2	2688	241.4	109	2.3	38	
	A_2	1	492	72.8	29	1.9	62	0.024
		2	506	77.6	26	1.9	63	
SW	A_1	1	2424	210.6	110	3.2	36	0.242
		2	2444	213.6	108	2.5	33	
		1	730	86.6	46	3.2	160	0.038
		2	744	85.2	46	3.2	155	

APPENDIX D

Mean mineral ion and water concentrations in first and second year twigs of thirteen tree and shrub species. Vertical lines connect those species which have concentrations not significantly different from one another at the 0.005 protection level (Duncan's New Multiple Range test). SEM= standard error of the mean.

First Year Twigs

Phosphorus
SEM= 0.01414213

Species	Concentration (percent)				Browse Preference	Nutrient Coordinate
Populus tremuloides	0.2291	|			L	5
Prunus virginiana	0.2055	|	|		H	3
Corylus americana	0.1838		|	|	L	2
Betula papyrifera	0.1829		|	|	M	2
Corylus cornuta	0.1744		|	|	L	1
Crataegus punctata	0.1720		|	|	L	5
Cornus rugosa	0.1669		|	|	H	3
Fraxinus pennsylvanica	0.1615		|	|	H	5
Quercus macrocarpa	0.1569			|	H	3
Cornus racemosa	0.1554			|	H	4
Viburnum rafinesquianum	0.1527			|	H	2
Ostrya virginiana	0.1457			|	L	5
Quercus rubra	0.1439			|	M	4

Potassium
SEM= 0.04618801

Species	Concentration (percent)					Browse Preference	Nutrient Coordinate
Viburnum rafinesquianum	1.1813	|				H	2
Corylus americana	1.0781	|				L	2
Corylus cornuta	0.9257					L	1
Quercus macrocarpa	0.7449		|			H	3
Populus tremuloides	0.7111		|			L	5
Fraxinus pennsylvanica	0.5598			|		H	5
Prunus virginiana	0.4966			|	|	H	3
Ostrya virginiana	0.4889			|	|	L	5
Crataegus punctata	0.4038				|	L	5
Cornus racemosa	0.3667				|	H	4
Quercus rubra	0.3603				|	M	4
Betula papyrifera	0.3551				|	M	2
Cornus rugosa	0.3513				|	H	3

Calcium
SEM= 0.06557435

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Cornus rugosa	1.4368	H	3
Crataegus punctata	1.3958	L	5
Quercus macrocarpa	1.3568	H	3
Populus tremuloides	1.3168	L	5
Corylus cornuta	1.2633	L	1
Ostrya virginiana	1.2302	L	5
Cornus racemosa	1.1416	H	4
Corylus americana	1.1213	L	2
Quercus rubra	1.0308	M	4
Viburnum rafinesquianum	0.9497	H	2
Prunus virginiana	0.7990	H	3
Fraxinus pennsylvanica	0.7334	H	5
Betula papyrifera	0.5138	M	2

Strontium
SEM= 3.23677254

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Cornus rugosa	62.7052	H	3
Crataegus punctata	50.4242	L	5
Cornus racemosa	49.6993	H	4
Corylus cornuta	45.7301	L	1
Ostrya virginiana	42.2908	L	5
Quercus macrocarpa	42.1886	H	3
Corylus americana	42.1753	L	2
Populus tremuloides	31.2518	L	5
Viburnum rafinesquianum	30.4508	H	2
Prunus virginiana	27.6865	H	3
Fraxinus pennsylvanica	26.9158	H	5
Quercus rubra	26.5403	M	4
Betula papyrifera	13.9068	L	2

Iron
SEM= 8.14433002

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Corylus americana	109.7704	L	2
Corylus cornuta	101.1024	L	1
Betula papyrifera	82.7496	M	2
Ostrya virginiana	70.5128	L	5
Quercus macrocarpa	51.8585	H	3
Viburnum rafinesquianum	49.7191	H	2
Populus tremuloides	46.1140	L	5
Cornus racemosa	43.8565	H	4
Fraxinus pennsylvanica	43.6452	H	5
Quercus rubra	40.0177	M	4
Cornus rugosa	39.7917	H	3
Prunus virginiana	35.6337	H	3
Crataegus punctata	35.4052	L	5

Magnesium
SEM= 0.01527525

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Quercus rubra	0.2000	M	4
Quercus macrocarpa	0.1767	H	3
Crataegus punctata	0.1757	L	5
Populus tremuloides	0.1650	L	5
Corylus americana	0.1618	L	2
Ostrya virginiana	0.1597	L	5
Corylus cornuta	0.1596	L	1
Prunus virginiana	0.1487	H	3
Fraxinus pennsylvanica	0.1409	H	5
Viburnum rafinesquianum	0.1117	H	2
Cornus rugosa	0.1085	H	3
Betula papyrifera	0.0968	M	2
Cornus racemosa	0.0944	H	4

Zinc
SEM= 7.94603157

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Populus tremuloides	135.6575	L	5
Betula papyrifera	116.5796	M	2
Viburnum rafinesquianum	79.7381	H	2
Corylus americana	58.4453	L	2
Crataegus punctata	53.2580	L	5
Fraxinus pennsylvanica	52.5457	H	5
Ostrya virginiana	48.1260	L	5
Corylus cornuta	43.9237	L	1
Prunus virginiana	42.0415	H	3
Quercus macrocarpa	39.1250	H	3
Quercus rubra	38.1555	M	4
Cornus rugosa	34.4105	H	3
Cornus racemosa	33.9323	H	4

Copper
SEM= 6.04598141

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Fraxinus pennsylvanica	51.3044	H	5
Prunus virginiana	30.5725	H	3
Crataegus punctata	22.2902	L	5
Viburnum rafinesquianum	21.7047	H	2
Populus tremuloides	21.4250	L	5
Quercus rubra	20.2217	M	4
Betula papyrifera	15.0421	L	2
Cornus racemosa	14.5818	H	4
Ostrya virginiana	13.5748	L	5
Corylus cornuta	11.4477	L	1
Quercus macrocarpa	10.8422	H	3
Corylus americana	9.9673	L	2
Cornus rugosa	7.6799	H	3

Molybdenum
SEM= 0.04654746

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Corylus americana	0.6966	L	2
Quercus macrocarpa	0.6136	H	3
Corylus cornuta	0.6133	L	1
Quercus rubra	0.5686	M	4
Ostrya virginiana	0.5112	L	5
Crataegus punctata	0.5111	L	5
Viburnum rafinesquianum	0.4920	H	2
Cornus rugosa	0.4474	H	3
Fraxinus pennsylvanica	0.4474	H	5
Betula papyrifera	0.4346	M	2
Prunus virginiana	0.4283	H	3
Populus tremuloides	0.4283	L	5
Cornus racemosa	0.3265	H	4

Manganese
SEM= 17.50419617

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Corylus americana	400.0000	L	2
Corylus cornuta	383.3333	L	1
Viburnum rafinesquianum	360.5251	H	2
Quercus macrocarpa	309.2664	H	3
Quercus rubra	267.4060	M	4
Ostrya virginiana	244.2677	L	5
Prunus virginiana	125.5686	H	3
Betula papyrifera	83.4187	M	2
Populus tremuloides	48.9536	L	5
Fraxinus pennsylvanica	28.3553	H	5
Crataegus punctata	26.1349	L	5
Cornus racemosa	19.9146	H	4
Cornus rugosa	18.2281	H	3

Boron
SEM= 1.62561703

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Corylus cornuta	28.3326	L	1
Quercus rubra	25.2778	M	4
Cornus rugosa	24.2109	H	3
Prunus virginiana	24.1486	H	3
Corylus americana	22.2460	L	2
Cornus racemosa	21.7012	H	4
Viburnum rafinesquianum	21.0770	H	2
Quercus macrocarpa	19.6537	H	3
Populus tremuloides	19.4419	L	5
Ostrya virginiana	19.3834	L	5
Fraxinus pennsylvanica	17.9272	H	5
Crataegus punctata	17.2212	L	5
Betula papyrifera	17.1166	M	2

Moisture Content
SEM= 0.01825741

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Populus tremuloides	0.5167	L	5
Prunus virginiana	0.5167	H	3
Cornus rugosa	0.4767	H	3
Corylus cornuta	0.4667	L	1
Quercus macrocarpa	0.4633	H	3
Corylus americana	0.4600	L	2
Viburnum rafinesquianum	0.4367	H	2
Ostrya virginiana	0.4333	L	5
Betula papyrifera	0.4300	M	2
Crataegus punctata	0.4233	L	5
Fraxinus pennsylvanica	0.4233	H	5
Cornus racemosa	0.4067	H	4
Quercus rubra	0.3800	M	4

Second Year Twigs

Phosphorus
SEM= 0.01000000

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Prunus virginiana	0.1627	H	3
Populus tremuloides	0.1584	L	5
Corylus americana	0.1451	L	2
Cornus rugosa	0.1418	H	3
Corylus cornuta	0.1379	L	1
Crataegus punctata	0.1355	L	5
Betula papyrifera	0.1222	M	2
Cornus racemosa	0.1201	H	4
Quercus rubra	0.1176	M	4
Fraxinus pennsylvanica	0.1174	H	5
Quercus macrocarpa	0.1170	H	3
Viburnum rafinesquianum	0.1110	H	2
Ostrya virginiana	0.1092	L	5

Potassium
SEM= 0.05446711

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Viburnum rafinesquianum	0.8642	H	2
Corylus americana	0.7022	L	2
Corylus cornuta	0.5720	L	1
Populus tremuloides	0.5707	L	5
Quercus macrocarpa	0.5036	H	3
Fraxinus pennsylvanica	0.3910	H	5
Prunus virginiana	0.3769	H	3
Crataegus punctata	0.3302	L	5
Ostrya virginiana	0.3186	L	5
Cornus racemosa	0.3116	H	4
Quercus rubra	0.2821	M	4
Cornus rugosa	0.2751	H	3
Betula papyrifera	0.2405	M	2

Calcium
SEM= 0.07724416

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Crataegus punctata	1.3805	L	5
Cornus rugosa	1.2066	H	3
Quercus macrocarpa	1.2012	H	3
Corylus cornuta	1.1942	L	1
Corylus americana	1.1800	L	2
Populus tremuloides	1.1584	L	5
Ostrya virginiana	1.0489	L	5
Cornus racemosa	1.0166	H	4
Prunus virginiana	0.7788	H	3
Viburnum rafinesquianum	0.7415	H	2
Quercus rubra	0.7311	M	4
Fraxinus pennsylvanica	0.5541	H	5
Betula papyrifera	0.4644	M	2

Strontium
SEM= 3.25514317

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Cornus rugosa	53.8595	H	3
Crataegus punctata	50.3917	L	5
Corylus americana	47.4222	L	2
Cornus racemosa	44.2241	H	4
Corylus cornuta	43.6924	L	1
Quercus macrocarpa	37.8010	H	3
Ostrya virginiana	36.0390	L	5
Populus tremuloides	28.8634	L	5
Prunus virginiana	26.0329	H	3
Viburnum rafinesquianum	23.9036	H	2
Fraxinus pennsylvanica	22.3830	H	5
Quercus rubra	19.8432	M	4
Betula papyrifera	13.9569	M	2

Iron
SEM= 11.66379070

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Corylus americana	154.1292	L	2
Corylus cornuta	120.1882	L	1
Betula papyrifera	91.4215	M	2
Ostrya virginiana	54.7957	L	5
Quercus macrocarpa	50.9492	H	3
Crataegus punctata	47.7953	L	5
Fraxinus pennsylvanica	47.2466	H	5
Viburnum rafinesquianum	42.6473	H	2
Prunus virginiana	40.5947	H	3
Cornus racemosa	39.6821	H	4
Cornus rugosa	39.6793	H	3
Populus tremuloides	33.9424	L	5
Quercus rubra	33.4932	M	4

Magnesium
SEM= 0.01000000

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Populus tremuloides	0.1418	L	5
Corylus americana	0.1360	L	2
Quercus rubra	0.1279	M	4
Corylus cornuta	0.1239	L	1
Quercus macrocarpa	0.1193	H	3
Ostrya virginiana	0.1178	L	5
Crataegus punctata	0.1131	L	5
Fraxinus pennsylvanica	0.1075	H	5
Prunus virginiana	0.0931	H	3
Viburnum rafinesquianum	0.0856	H	2
Cornus rugosa	0.0821	H	3
Cornus racemosa	0.0800	H	4
Betula papyrifera	0.0738	M	2

Zinc
SEM= 8.56152153

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Populus tremuloides	117.3366	L	5
Betula papyrifera	111.3394	M	2
Viburnum rafinesquianum	70.2452	H	2
Crataegus punctata	68.6412	L	5
Corylus americana	63.8388	L	2
Fraxinus pennsylvanica	39.8725	H	5
Corylus cornuta	38.7809	L	1
Ostrya virginiana	37.1926	L	5
Quercus macrocarpa	34.5842	H	3
Cornus racemosa	33.4340	H	4
Cornus rugosa	28.8337	H	3
Quercus rubra	26.7531	M	4
Prunus virginiana	26.3703	H	3

Copper
SEM= 9.19483089

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Fraxinus pennsylvanica	49.4194	H	5
Crataegus punctata	40.8823	L	5
Cornus racemosa	20.6625	H	4
Prunus virginiana	15.7813	H	3
Quercus macrocarpa	15.2779	H	3
Populus tremuloides	14.5442	L	5
Viburnum rafinesquianum	13.2754	H	2
Betula papyrifera	13.2369	M	2
Corylus americana	13.0385	L	2
Cornus rugosa	12.7602	H	3
Ostrya virginiana	10.6202	L	5
Quercus rubra	10.2741	M	4
Corylus cornuta	8.5331	L	1

Molybdenum
SEM= 0.04932882

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Corylus cornuta	0.5622	L	1
Corylus americana	0.5240	L	2
Viburnum rafinesquianum	0.4730	H	2
Ostrya virginiana	0.4665	L	5
Quercus macrocarpa	0.4538	H	3
Quercus rubra	0.4474	M	4
Populus tremuloides	0.4283	L	5
Fraxinus pennsylvanica	0.4092	H	5
Betula papyrifera	0.3901	M	2
Crataegus punctata	0.3837	L	5
Prunus virginiana	0.3647	H	3
Cornus rugosa	0.3265	H	3
Cornus racemosa	0.3138	H	4

Manganese
SEM= 28.58767700

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Quercus macrocarpa	277.8833	H	3
Corylus americana	268.5161	L	2
Corylus cornuta	248.4007	L	1
Viburnum rafinesquianum	246.7879	H	2
Ostrya virginiana	185.5836	L	5
Quercus rubra	180.8596	M	4
Prunus virginiana	86.3407	H	3
Betula papyrifera	64.6541	M	2
Populus tremuloides	37.0891	L	5
Fraxinus pennsylvanica	23.9899	H	5
Crataegus punctata	23.4413	L	5
Cornus racemosa	17.7184	H	4
Cornus rugosa	11.8276	H	3

Boron
SEM= 1.19801140

Species	Concentration (ppm)	Browse Preference	Nutrient Coordinate
Cornus rugosa	22.5556	H	3
Corylus cornuta	22.4535	L	1
Quercus rubra	21.8686	M	4
Cornus racemosa	21.6246	H	4
Corylus americana	20.8164	L	2
Prunus virginiana	20.7711	H	3
Crataegus punctata	18.1579	L	5
Populus tremuloides	17.0338	L	5
Fraxinus pennsylvanica	16.1580	H	5
Viburnum rafinesquianum	15.9453	H	2
Ostrya virginiana	15.6563	L	5
Quercus macrocarpa	15.4284	H	3
Betula papyrifera	12.9413	M	2

Moisture Content
SEM= 0.01000000

Species	Concentration (percent)	Browse Preference	Nutrient Coordinate
Populus tremuloides	0.4900	L	5
Prunus virginiana	0.4833	H	3
Cornus rugosa	0.4600	H	3
Corylus cornuta	0.4433	L	1
Viburnum rafinesquianum	0.4233	H	2
Corylus americana	0.4200	L	2
Betula papyrifera	0.4167	M	2
Ostrya virginiana	0.4100	L	5
Quercus macrocarpa	0.4100	H	3
Cornus racemosa	0.4000	H	4
Crataegus punctata	0.3967	L	5
Quercus rubra	0.3967	M	4
Fraxinus pennsylvanica	0.3933	H	5