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TALL SHRUB LAYER BIOMASS IN CONIFER PLANTATIONS OF NORTHEASTERN MINNESOTA

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Management for wildlife habitat on public land occurs primarily through manipulation of forest stands for timber management. Common examples of stand manipulation are: regeneration of new stands via harvesting followed by natural reproduction, seeding, or planting; release of regenerated stands from competing vegetation; and later thinning or other stand improvement treatments. Because good timber management is not necessarily good wildlife habitat management (Thomas *et al.* 1976), land managers should know the impacts that silvicultural practices might have on wildlife habitat. This kind of information can help meet legislative and policy requirements that land managed by the USDA Forest Service support an abundance and diversity of wildlife.

Large-scale planting programs in the Lake States began with the Civilian Conservation Corps in 1933 (Krefting 1975). By 1966 more than 1 million acres (404,700 ha) of conifers had been planted in Michigan (Gysel 1966). The Superior National Forest of northeastern Minnesota has established about 300,000 acres (121,410 ha) of conifer plantations. Conifer plantations make up about 10 percent of the Forest's Isabella and Halfway (now part of the Kawishiwi) Ranger Districts, where this study was conducted (Peek *et al.* 1976).

The acreage of conifer plantation in northeastern Minnesota will probably increase in response to more intensive forest management mandated by recent Federal legislation that restricts timber harvest in the Boundary Waters Canoe Area Wilderness.

The principal vertebrate wildlife using these plantations for browse (food) are moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), and snowshoe hare (*Lepus americanus*) (Grigal and Moody 1980, Mooty 1976, Peek *et al.* 1976).

This paper describes the impacts of some common silvicultural practices on biomass production by tall shrubs and small broadleaf trees in conifer plantations successfully established between 1945 and 1974 near Isabella, Minnesota. Portions of this biomass—the leaf and current annual woody twig growth—serve as potential browse for wildlife.

METHODS

Study plantations on relatively uniform soils (coarse loamy Dystric Eutrochrepts)[1] were selected from within a 33-mi^2 (85.5 km^2) area near Isabella, Minnesota (lat. 47° 35'N, long. 91° 20'W). Parts of the area had been logged for red pine (*Pinus resinosa* Ait.) and white pine (*Pinus strobus* L.) during northern Minnesota's early logging period (ca. 1900-1920). However, the sample was selected from plantations established following the clearcut of natural stands of pine (jack pine, *Pinus banksiana* Lamb.) or mixed pine and spruce (usually black spruce, *Picea mariana* (Mill.) B.S.P.) during the mid-1940's through the 1970's.

Sample selection was designed to represent a spectrum of plantation ages and the silvicultural techniques practiced in the study area over the 30-year period. These conditions were represented on a cover-type map with overlays (Hagen and Meyer 1977) that depicted plantation establishment dates, tree species planted, and site preparation and plantation release methods. Based on the overlays, plantations

[1]*Personal communication with D. F. Grigal.*

were arbitrarily classed by 5-year segments from earliest available (1945-1949) to most recent (1970-1974). The plantations were also categorized on the basis of two silvicultural practices: (1) site preparation for planting; and (2) release from competing vegetation; and on the species of trees planted.

Site preparation methods included: (1) no record of a site preparation treatment applied; (2) mechanical disking of the ground surface, probably by an Athens-type disk plow (Rudolf 1950); (3) dozer-blade shearing of woody stems and scraping of at least some of the forest floor material and depositing it in specific areas, generally windrows (rock-raking) (Noble *et al.* 1977); and (4) chemical herbicide (usually either 2,4-D, or a mixture of 2,4-D and 2,4,5-T) to the post-logging vegetation. Plantation release methods included: (1) chemical (in more recent years usually 2,4-D herbicide applied by helicopter (Hagen and Meyer 1977), but earlier could have included a mixture of 2,4-D and 2,4,5-T applied less effectively from fixed-wing aircraft); (2) manual (hand removal of competing vegetation one or more times); (3) manual plus chemical (a combination of both types of release, usually a manual release followed by a chemical release several years later); and (4) unknown (no record of release). Tree species planted were categorized as: (1) pine (either red pine, jack pine, or a combination of both); (2) pine and spruce (white spruce, *Picea glauca* (Moench) Voss); or (3) spruce.

The plantations were randomly chosen on the cover-type map and overlays by use of random numbers selected from right angle baselines drawn on the map. Samples were drawn until at least 3 sites were picked representing all categories of species planted, site preparation, and plantation release practiced within each of the 5-year establishment periods. Because silvicultural technology changed, not all of the listed practices were represented in each establishment period. For example, disking for site preparation was not applied in plantations established after 1964, chemical site preparation was not practiced before 1965, no plantations were established without site preparation later than 1965, and rock-raking was not used until 1960.

Diameters of shrubs and deciduous tree species under 1 inch (2.5 cm) diameter at breast height (d.b.h.) were measured to the nearest one-tenth of an inch (0.25 cm) at a point 6 inches (15 cm) above ground level in circular mil-acre (4.05 m^2) plots. Shrub diameters were tallied by species in 10 plots distributed systematically throughout a homogeneous portion of each plantation. For efficiency, stems were tallied in only one-half of each mil-acre plot in plantations where shrubs were especially abundant.

Diameters were used to estimate ovendry weight of the leaves, current annual woody twigs, and total aboveground stem wood through use of allometric estimation equations previously developed for trees and shrubs of this area (Grigal and Ohmann 1977, Ohmann *et al.* 1976).

Biomass estimates for leaf (LEAF), current annual wood twig (TWIG), and total aboveground stem wood (WOOD) were summarized by plantation establishment period (YEAR), method of plantation release (RELEASE), method of site preparation (PREP), and tree species planted (SPECIES).

Total plantation shrub layer biomass and biomass of species that were represented in at least 15 of the 28 treatment categories were, after logarithmic transformation, analyzed for difference among treatments and treatment combinations through three-way analyses of variance (ANOVAs).

The effect of treatment categories was also assessed through Multiple Classification Analysis (MCA). MCA is a multivariate technique for examining the simultaneous interrelations between several treatments and a dependent variable (Andrews *et al.* 1973). It is especially useful when the treatments are correlated to some degree and where the attributes examined are not experimentally manipulated (Nie *et al.* 1975), as in this study. A unique feature of MCA is the ability to show the effect of each treatment category on the dependent variable (biomass) both before and after taking into account the effects of the other treatment(s) being considered. The classification computes a grand mean for the dependent variable (biomass) and for category means of each treatment, expressed as deviations from the grand mean. These deviations indicate the effect of each treatment category. The analysis also provides values for each treatment category, expressed as deviations from the grand mean after adjustment for other treatments. These adjusted values indicate the "true" effects of the treatment category on the dependent variable—the effects remaining after variation due to other treatments has been accounted for.

RESULTS AND DISCUSSION

The sample consisted of nine or more plantations for each of the establishment periods except for 1970-1974 when not enough plantations were available for sampling (table 1). Some of the PREP, RELEASE, and SPECIES categories also had limited representation and only a minimum 3 samples were selected from each of them because of their scarcity in the plantation population (table 1).

Two of the independent variables, YEAR and PREP, were significantly positively correlated. This probably reflects changes in site preparation practices. YEAR and SPECIES, as well as PREP and SPECIES were also slightly positively related. YEAR and RELEASE, PREP and RELEASE, and SPECIES and RELEASE were weakly negatively related:

Independent Variable	Pearson's R	Probability
YEAR-PREP	0.7134	0.000
YEAR-RELEASE	-0.1100	.216
YEAR-SPECIES	.2022	.073
PREP-RELEASE	-0.0691	.312
PREP-SPECIES	.1378	.162
RELEASE-SPECIES	-0.1569	.131

It is important to recognize the degree of correlation because positively related treatments, when considered together, will explain less of the variation than the sum of them considered separately. On the other hand, negatively related treatments that are positively related to the dependent variable will, when considered together, explain more of the variation in the dependent variable than the sum of them considered separately. The independent variables YEAR and PREP are correlated sufficiently so that when considered together in a three-way ANOVA or MCA the amount of variation explained is less than actually present.

None of the 28 woody species was found in the sample plots within every plantation, and only 7 species were tallied in more than half (27) of the plantations (table 2). However, these seven (the tall shrubs *Corylus, Amelanchier, Alnus, Prunus,* and *Salix;* and the trees under 1 inch d.b.h., *Acer* and *Populus)* accounted for more than 80 percent of the total estimated LEAF, TWIG, and WOOD biomass. Although not as dominant, the smaller shrubs can provide browse, especially because they tend to produce a higher proportion of their biomass as leaves and twigs. For example, for the tall shrub and tree species there was a generally consistent ratio of LEAF to WOOD biomass of about 0.14, and TWIG to WOOD biomass ratio of about 0.04. Many of the smaller shrubs, however, had higher LEAF and TWIG TO WOOD biomass ratios; for example, *Rubus strigosus* 0.66 and 0.17, *Rubus parviflorus* 0.79 and 1.0, *Rosa acicularis* 0.38 and 0.16, *Rosa blanda* 0.29 and 0.17, and most of the *Lonicera* species (*L. oblongifolia* 0.33 and 0.21, *L. hirsuta* 0.22 and 0.08, and *L. dioica* 0.40 and 0.15). Not only do these species have browse potential but some, *Rosa* and *Lonicera* for example, are highly preferred snowshoe hare and white-tailed deer foods during some seasons (Grigal and Moody 1982[2]).

In addition to total plantation biomass, 15 species were represented by sufficient biomass in the various categories to test for differences among treatments through ANOVA. Three-way ANOVAs were conducted to examine the combined effects of the silvicultural practices on the estimated LEAF, TWIG, and WOOD biomass values in addition to individual treatment effects. Some ANOVAs could not be conducted because the close relation between chemical site preparation and spruce species planted (PREP and SPECIES) resulted in a singular matrix. Of the 96 3-way ANOVAs conducted, 38 LEAF, TWIG, or WOOD cases were significant at the $p = \geqslant 0.10$ level for one or more sources of variation (see Appendix).

While ANOVA indicates the presence of differences among treatment categories, it does not indicate which treatment categories differ from the oth-

[2]*Personal communication with Lynn Rogers.*

Table 1.--Independent variable categories against which the biomass estimates of the tall shrub layer (LEAF), current annual woody twig growth (TWIG), and total aboveground wood (WOOD) were tested from 53 conifer plantations near Isabella, Minnesota

Establishment period		Site preparation		Plantation release		Species planted	
YEAR	Plantations	PREP	Plantations	RELEASE	Plantations	SPECIES	Plantations
	Number		Number		Number		Number
1945-1949	9	None	11	Chemical	17	Pine	38
1950-1954	9	Disk	21	Manual	21	Pine and Spruce	12
1955-1959	9	Rock-rake	18	Manual plus chemical	3	Spruce	3
1960-1964	13	Chemical	3	No record	12		
1965-1969	9						
1970-1974	4						

Table 2.--Mean and standard error estimates for leaf, current annual woody twig, and total aboveground woody stem biomass (ovendry) of shrub layer species in conifer plantations near Isabella, Minnesota

Species	Plantations	LEAF $\bar{X}$	LEAF SE	TWIG $\bar{X}$	TWIG SE	WOOD $\bar{X}$	WOOD SE
	Number	Pounds/acre					
Total (stand totals all shrub layer species)	53	285.6	26.5	75.9	7.4	2,059.4	212.7
Rubus strigosus	51	20.2	4.0	5.1	.8	30.6	6.2
Corylus cornuta	50	110.4	15.0	26.0	3.3	841.7	110.1
Rosa acicularis	48	6.2	.9	2.7	.4	16.4	2.5
Amelanchier spp.	43	20.6	3.1	5.7	.8	166.8	31.4
Alnus crispa	34	109.7	20.1	33.2	6.1	935.1	172.7
Populus tremuloides	34	43.0	12.9	5.2	1.4	252.6	72.0
Prunus pensylvanica	31	9.3	2.0	2.4	.5	83.6	17.3
Lonicera canadensis	26	2.3	.4	.8	.1	13.6	2.5
Salix spp.	24	26.1	8.6	3.2	1.0	233.4	87.6
Betula papyrifera	19	2.0	.6	.8	.4	18.2	8.2
Lonicera oblongifolia	18	.8	.4	.5	.3	2.5	1.3
Acer spicatum	15	21.0	5.4	12.1	3.3	240.3	58.1
Prunus virginiana	15	12.4	2.5	2.7	.7	65.9	17.0
Cornus rugosa	13	21.4	9.7	4.5	2.0	85.6	42.9
Lonicera hirsuta	12	1.7	.4	.7	.2	7.8	3.7
Acer rubrum	8	26.8	15.9	21.7	9.8	200.9	118.7
Rosa blanda	6	2.4	.8	1.4	.5	8.2	3.4
Ribes spp.	4	1.3	1.2	.6	.5	11.7	11.3
Sorbus americana	3	2.5	1.5	.9	.6	19.4	13.6
Lonicera villosa	3	2.1	1.3	.4	.2	9.0	4.1
Lonicera dioica	2	.8	0	.3	0	1.9	0
Populus balsamea	2	2.8	2.8	.6	.6	25.2	24.1
Alnus rugosa	1	31.4	—	29.7	—	311.8	—
Cornus stolonifera	1	23.2	—	3.5	—	124.9	—
Rhamnus alnifolia	1	15.1	—	3.3	—	86.9	—
Ribes hirsuta	1	.1	—	.1	—	.4	—
Rubus parviflorus	1	55.3	—	70.2	—	70.2	—
Viburnum rafinesquianum	1	8.3	—	.9	—	32.3	—

ers. Means that were detected by the Student-Newman-Keuls test as significantly different ($p = \geqslant 0.05$) included 10 categories of YEAR, four each of PREP and SPECIES, and two of RELEASE (see Appendix).

The relation of biomass to each treatment category is difficult to interpret because of the complex relation of treatments and categories and their influence on the resulting biomass values. The ANOVA and MCA analyses help to clarify these relations by making it possible to examine the influence of a treatment and its categories after adjustment for the effect of the other treatments. Below, I present summary interpretations of these analyses. However, because the interpretations are based on adjusted values, the summary does not in all cases conform to the influence levels depicted in Appendix figure 1.

Ecological landtypes for the Superior National Forest have recently been described although they have not been extensively mapped. The most probable ELTs for the plantations in this study are: ELT-11 (UDHD) Upland Deep Loamy over Sandy Dry, ELT-13 (UDLDC) Upland Deep Loamy Dry Coarse, and ELT-14 (UDLDM) Upland Deep Medium Loamy Dry. These ELTs are estimated to occupy 10, 8, and 11 percent of the land area within the Superior National Forest, respectively. The results presented here would be most applicable to conifer plantations located on these ELTs.

Plantation Total

The treatment PREP explains a statistically significant amount of the variation in LEAF and WOOD plantation biomass. Because total biomass is comprised of a combination of species for which greater or lesser biomass for any one species in any treatment category may balance out, it is not surprising that the variation accounted for by a treatment may be statistically significant, but not very high. For LEAF and WOOD, the treatment PREP is most important, explaining 15 and 18 percent of the biomass variation, respectively. The other statistically non-significant variation trends for LEAF and WOOD are SPECIES (12 and 14 percent), RELEASE (7 and

11 percent), and YEAR (2 and 5 percent). For TWIG the ranking is PREP 14 percent, RELEASE 10 percent, SPECIES 9 percent, and YEAR 2 percent.

The most important treatment categories associated with above-average total plantation biomass values were older plantations that had been prepared by disking, planted to pine, and later released from competing vegetation by manual methods. Categories associated with below-average biomass values were sites that had been prepared by chemical methods for planting to spruce and later released by chemical methods.

There were no statistical differences in total shrub stratum biomass between 5-year establishment periods. Plantation shrub layer totals were lower than those found in either 5-year-old post-logging or mature aspen stands on good sites, 5-year-old aspen stands after fire, and mature stands of mixed pine-aspen-birch (table 3). Plantation totals were higher than shrub layer biomass in mature jack pine stands on shallow soils over bedrock. They were about the same as those found in similar conifer plantations and mature stands in the Isabella area and in naturally regenerating 5-year-old conifer stands after fire (table 3).

Table 3.--Mean biomass estimates (ovendry) of tall shrub layers from various studies in northeastern Minnesota

Source	Stand age (years)						
	1-5	6-10	11-15	16-20	21-25	26-30	Mature
	Pounds/acre						
This study[1]	2,034 (4)[2]	2,332 (9)	2,035 (13)	2,086 (9)	2,914 (9)	2,631 (9)	
Kernik[3]							
Plantations	1,202 (1)	230 (1)	2,265 (2)		2,276 (3)	2,339 (7)	
White cedar							1,331 (1)
Black spruce							2,747 (2)
Mixed red and white pine With subcanopy of aspen-birch							4,943 (1)
Ohmann and Grigal (1979)[4]							
Jack pine-fir	2,928 (1)						
Jack pine-oak	5,705 (1)						
Jack pine-black spruce	3,074 (1)						
Aspen-birch	15,387 (1)						
Silkworth (1980)[5]							
Aspen on good sites	32,834 (2)						3,729 (2)
Green (1979)[6]							
Jack pine on shallow soil							143
Jack pine on deep till							2,680 (15)

[1]Plantation conifer stands after clearcut harvest of jack pine-black spruce. Includes deciduous tree species under 1-inch d.b.h. and tall shrubs.
[2]Number of stands in parentheses.
[3]Personal communication. Plantation conifer stands after clearcut harvest of jack pine-black spruce, and mature uncut communities. Shrub layer includes deciduous tree seedlings under 1-inch d.b.h. and tall shrubs.
[4]Natural conifer (seed) and aspen (sucker) stands 5 years after fire. Shrub layer total includes deciduous trees and tall shrubs.
[5]Natural sucker stands after whole-tree harvest of aspen; uncut mature aspen stands on good sites. Shrub layer data includes regenerating aspen and tall shrubs 5 years after logging but includes tall shrubs only in the uncut stands.
[6]Mature, uncut, even-age jack pine stands more than 50 years old on either shallow soils over bedrock or on deep tills. The tall shrub layer data includes tall shrubs and tree seedlings. However, tree seedlings comprised a small proportion of the layer (a maximum of 8.6 pounds//acres in any stand). Most of the seedlings were decidous tree species.

Acer spicatum

Mountain maple was recorded in only 15 plantations, but was represented in all treatment categories. Probably because of its low occurrence, none of the treatments or treatment combinations explained a statistically significant amount of the variation in mountain maple biomass. RELEASE explained from 25 to 35 percent of the biomass variation, YEAR explained 9 to 16 percent, PREP explained 4 to 8 percent, and SPECIES explained 4 percent.

Above-average biomass values were associated with older plantations that had received only a disk treatment before planting; those that were planted to pine; and those that were released manually. Below-average biomass values were associated with plantations that had been prepared for planting by chemical methods or those that had been released from competing vegetation through a combination of manual plus chemical treatments.

Mountain maple is a prominent understory tall shrub or small tree of northern forest types. It grows in either sunlight or shade but does best where neither shade nor sunlight is extreme (Hosier 1974). The species reproduces most commonly by sprouting from underground stems, but it can also reproduce from seed, layered branches, and root suckers (Hosier 1974). Ground surface disturbance can eradicate mountain maple if the plants are uprooted and the stems severed. However, if the stems are simply tipped over or mashed down, or if they are just severed at the ground surface, sprouting will be stimulated (Hosier 1974). The species is resistant to foliar application of 2,4-D and 2,4,5-T herbicides (Benzie 1977). Herbicides can stimulate sprouting (Hosier 1974), but the shrub can be controlled by severing the stem and applying 2,4,5-T to the stump.

In a study of mature virgin forest communities of the region, mountain maple was recorded in 18 percent of jack pine-oak community-type stands, 29 percent of jack pine-black spruce stands, 71 percent of jack pine-fir stands, 77 percent of aspen-birch stands, and 100 percent of the maple-aspen-birch stands (Ohmann and Ream 1971). In this region, the species is apparently more representative of mesic conifer and hardwood communities than of dryer jack pine community-types. Mountain maple's minimal representation makes it difficult to develop strong conclusions about the species' response to silvicultural treatments. The shrub's biomass distribution is about what would be expected based on its known growth habits. Site preparation through chemical treatmen and plantation release by manual plus chemica treatment would normally be expected to enhanc sprouting rather than result in less biomass as foun here, unless the herbicides were applied shortly afte the stems of mountain maple were severed.

Alnus crispa

Green alder was tallied in 34 plantations and wa represented in all treatment categories except plan tations prepared by chemical methods and plante to spruce. The treatment YEAR was the dominan influence on green alder biomass. Treatment com binations YEAR-PREP-SPECIES, YEAR-PREP RELEASE, and YEAR-SPECIES-RELEASE all ex plained a significant amount of the variation in gree alder biomass. YEAR explained 46 to 53 percent o the variation in LEAF, TWIG, and STEM biomass The other treatments explained less than 2 percen each.

Above-average biomass values were associated wit 5- to 15-year-old plantations, and to a minor degre those sites that had been prepared for planting t pine by rock-raking and later manual release fron competing vegetation. The most adverse treatmen category was chemical site preparation: the specie was not recorded in those plantations in spite of it presence in other plantations of the same age cate gory.

Green alder is a circumpolar species (Johnson 1968 common in the Lake Superior region (Rosendah 1955). It is a common dominant understory shrub o conifer plantations in northeastern Minnesota (Pee *et al.* 1976). After establishment by seed, alders ca spread or persist by sprouting, layering, under ground stems, and suckers (Healy and Gill 1974 Alder is susceptible to both 2,4-D and 2,4,5-T her bicides (Arend and Roe 1961). Green alder's capacit for reproducing by vegetative means after disturb ance and its susceptibility to herbicides may explai the biomass distribution found in this study. Mor biomass was found in intermediate-age plantation that were mostly prepared for planting by rock-rak ing (14 of 17 plantations in that time period) wher alder could have responded to the disturbance b producing more aerial stems vegetatively. Less bi omass was found in plantations subjected to chem ical treatment.

Amelanchier spp.

Juneberry was sampled in 45 plantations and was represented in all treatment categories. The treatment combination YEAR-SPECIES-RELEASE explained a statistically significant amount of the variation in juneberry biomass. YEAR explained 18 to 20 percent of the LEAF, TWIG, and STEM biomass variation; SPECIES explained 14 percent; RELEASE explained 13 to 15 percent; and PREP explained 12 to 14 percent.

The treatment categories associated with above-average biomass values were: (1) older plantations that had been prepared for planting to pine by disking, (2) older plantations that had received no site preparation before planting, (3) plantations that had been manually released from competition, and (4) plantations where no release activity was recorded. The most important categories associated with less biomass were the chemically treated plantations, especially those receiving both chemical site preparation for planting spruce and also later chemical release. Shrubs of the genus *Amelanchier* grow most frequently in moist soils (Larson 1974), but some species of the genus are commonly found on upland sandy soils and dry rocky ridges. Juneberry is a common understory shrub of conifer forests and plantations in northeastern Minnesota (Lakela 1965, Peek *et al.* 1976). Juneberry reproduces by seed and from suckers. Although its growth and reproduction are best in full sunlight, it also tolerates shade (Larson 1974). Juneberry is resistant to 2,4-D herbicide but is susceptible to 2,4,5-T herbicide (Benzie 1977).

Consistent with the species' growth habits and response to management practices, more juneberry biomass was found in older plantations where it would have had time to recover from site disturbance (disk preparation for planting and manual plantation release). Juneberry biomass was also greater in those plantations that received no site preparation for planting. Less biomass was associated with plantations that received chemical treatment (assuming a mixture of D-T herbicide).

Betula papyrifera

White (paper) birch (<1 inch d.b.h.) was tallied in 19 plantations and was represented in all treatment categories except plantations treated with chemicals before planting spruce. The treatment combinations YEAR-PREP-SPECIES and YEAR-SPECIES-RELEASE explained a significant amount of the variation in birch biomass. YEAR explained from 48 to 55 percent of the variation, followed by PREP (3 to 15 percent), RELEASE (3 to 6 percent), and SPECIES (1 to 5 percent).

The most important treatment categories associated with above-average white birch biomass were 5- to 10-year-old plantations that had been prepared for planting by rock-raking and then later chemically released. The most important treatment categories associated with below-average birch biomass were older plantations that had received no site preparation with no subsequent release recorded. Because white birch is a tree species, the low biomass values associated with the older plantations probably show the growth of birch out of the 1-inch diameter class.

White (paper) birch, a widespread tree species in northern North America (Viereck and Little 1972), is common throughout the Lake States (Folwells 1965). It grows on a wide range of soils and soil moisture conditions, reproducing from seed (given a suitable seed bed) or from sprouts after cutting or fire (Folwells 1965), especially if the stems are less than 60 years old (Tubbs 1977). White birch is a fast-growing but short-lived tree that is normally replaced after one generation. However, in the northern Lake States, it may maintain itself through sprouting and gap replacement to become a component of mature fir-birch communities. White birch is susceptible to both 2,4-D and 2,4,5-T herbicides (Arend and Roe 1961).

More white birch biomass was found in plantations where site preparation and herbicide release were practiced; less biomass was found in plantations where no site preparation and/or release treatments were applied. These findings are consistent with birch's sprouting ability after disturbance and its need for mineral soil seedbeds. Absence of white birch in the three plantations chemically prepared for planting to spruce in the 1965-1969 period is consistent with the species' susceptibility to herbicides.

Cornus rugosa

Round-leaf dogwood was tallied in 13 plantations and was not represented in the youngest establishment period (1- to 5-year-old) or on sites prepared by chemical treatment for planting spruce. None of the treatment combinations explained a statistically significant amount of the variation in dogwood biomass. PREP explained 35 percent of the variation, followed by RELEASE (28 to 29 percent), YEAR (17 to 18 percent), and SPECIES (2 percent).

Older plantations that had been prepared for planting by a disk treatment and that later received a manual plus chemical or a chemical release contained above-average dogwood biomass. Younger plantations, sites prepared for planting by rock-raking or chemicals and plantations with no recorded release or only a manual release contained the least dogwood biomass. Thus, greater dogwood biomass is associated with less intensive site preparation and severe release; less dogwood biomass is associated with younger plantations, intensive site preparation, and least release.

Round-leaf dogwood is an infrequent understory shrub of many northern forest types, mostly dry to well-drained woodlands (Lesser and Wistendahl 1974) and rocky wooded slopes (Rosendahl 1955, Lakela 1965). In a study of nearby mature virgin forests, this species was recorded only in the more mesic hardwood and nonpine coniferous types (Ohmann and Ream 1971). In another study of 33-year-old post-fire communities in the area, round-leaf dogwood was recorded in the aspen-birch and birch communities but not in the jack pine-birch and jack pine communities (Ohmann *et al.* 1973). The distribution of dogwood biomass found here suggests that the shrub is not very tolerant to site disturbance (rock-raking) or canopy shade (less biomass in the plantations not released).

Corylus cornuta

Beaked hazel was tallied in 50 of the plantations and was represented in all treatment categories. The treatment PREP explained 15 percent of the biomass variation, followed by YEAR (14 percent), SPECIES (11 percent), and RELEASE (9 to 10 percent), for LEAF, TWIG, and WOOD.

The most important treatment categories associated with above-average biomass values were older plantations that had been prepared for planting to pine or a combination of pine and spruce by disking and later released only by manual methods or for which no release was recorded. The most important categories associated with below-average biomass values were younger plantations that had been chemically prepared for planting to spruce and/or later chemically released from competition.

Beaked hazel is a common understory species of conifer plantations in northeastern Minnesota (Peek *et al.* 1976). After initial establishment in a stand by seed, hazel can produce many aerial stems vegetatively from underground stems (Stearns 1974). Although it is a pioneer successional species tha grows best where overhead shade allows more tha 30 percent of full sunlight, it will persist in matur conifer stands on light soils (Stearns 1974), as i these plantations. Hazel is susceptible to chemica herbicides (Stearns 1974). Disk site preparation ap plied in midsummer turns up the underground or gans of shrubs, setting back their growth for severa years (Eyre and Zehngraff 1948). More hazel bio mass was present in older plantations where haze would have had sufficient time to recover from th disk site preparation treatment and where no chem icals were later applied for plantation release. Les hazel biomass was found in plantations that had re ceived a chemical treatment to prepare the site fo planting and/or to release the conifers after estab lishment.

Lonicera canadensis

Fly-honeysuckle was measured in 26 plantation and was represented in all but one treatment cate gory (manual plus chemical release). None of th treatment combinations explained a statistically sig nificant amount of the variation in honeysuckle b omass. The most important treatment was YEAF but it explained only 9, 13, and 12 percent of th variation in LEAF, TWIG, and WOOD, respectivel RELEASE explained 6 to 8 percent, SPECIES 1 t 2 percent, and PREP 1 percent.

Treatment categories associated with above-av erage biomass values were 10- to 15-year-old plan tations that had been prepared for planting to pin by rock-raking and that were manually released fron competing vegetation. Categories associated wit below-average biomass values were: (1) plantation older than 15 years, (2) more recent plantations tha had been chemically prepared for planting to spruc and (3) plantations chemically released from com peting vegetation.

Fly-honeysuckle is an upright straggly shru (Lakela 1965) found commonly throughout cool moi woods of the coniferous region (Rosendahl 1955). is shade tolerant and can compete and persist unde canopy shade, but it normally will not dominate site (Jackson 1974). It can reproduce by seed and b shoots from a spreading root system (Jackson 1974

Lonicera hirsuta

Hairy-climbing honeysuckle was tallied in 1 plantations and was not represented in the 197

1974 establishment period or in plantations released by a manual plus chemical combination. None of the treatment combinations explained a significant amount of the variation in honeysuckle biomass. PREP explained 32 to 41 percent of the variation in biomass, followed by YEAR (31 to 36 percent), SPECIES (3 to 20 percent), and RELEASE (8 to 11 percent).

The categories associated with greater biomass were older plantations that had received only a disk treatment or no site preparation before planting pine and plantations that received no release or only a manual release. The categories associated with less biomass were younger plantations that had been rock-raked (or chemical prepared before planting spruce), and later chemically released from competing vegetation.

Hairy-climbing honeysuckle is a high twining vine (Lakela 1965) that is common but not abundant in cool, moist coniferous forests on dry, well-drained soils (Grimm 1957, Van Dersal 1938). This shrub, a strong competitor that can persist under forest shade, can reproduce by seed or by shoots from a spreading root system (Jackson 1974).

Lonicera oblongifolia

Swamp fly-honeysuckle was recorded in 18 plantations and was represented in all treatment categories except the 1970-1974 establishment period and manual plus chemical release category. None of the treatments explained a significant amount of the variation in biomass. The lack of statistical significance is probably the result of its occurrence in few plantations. The most important treatment was YEAR, which explained 32 to 33 percent of the variation followed by PREP (18 to 19 percent), SPECIES (16 to 17 percent), and RELEASE (2 percent).

Above-average biomass was associated with 10- to 20-year-old plantations that had received no preparation or only a disk treatment before planting of pine and that were later chemically released from competing vegetation. Below-average biomass was associated with older plantations with plantations where no release was recorded, and with plantations that received only a manual release treatment.

Swamp fly-honeysuckle is a small, erect, somewhat straggly shrub that grows in moist habitats (Van Dersal 1938). It is common but not abundant in northern forests of this region (Rosendahl 1955). Here it was recorded in 34 percent of the plantations. It can reproduce from seed and by root suckers (Jackson 1974).

Because none of these honeysuckles normally dominate forest sites, little effort has been made to control them through management practices (Jackson 1974). This study suggests that the biomass distribution of these shrubs is influenced primarily by their susceptibility to chemical herbicides, and secondarily (at least for fly-honeysuckle and swamp fly-honeysuckle) by reduced growth and vigor as the plantation canopy closes and shade increases about 15 to 20 years after establishment.

Populus tremuloides

Quaking aspen (less than 1 inch d.b.h.) was represented in all treatment categories and recorded in 34 plantations. The treatment combinations YEAR-PREP-RELEASE and YEAR-SPECIES-RELEASE explained a significant amount of the variation in aspen biomass. YEAR explained 45 to 50 percent of the biomass variation. PREP explained 14 to 16 percent, RELEASE explained 6 to 9 percent, and SPECIES explained less than 1 percent.

Treatment categories associated with above-average biomass values were younger plantations, and to a lesser extent, those sites that had been prepared by rock-raking or disking, planting to pine, and later release by manual methods or for which no release was recorded. These latter categories were associated with younger plantations but not the youngest (1- to 5-year-old) plantation group. The most important categories associated with less biomass were the older plantations, plantations that had been chemically prepared for planting spruce, and plantations that had been chemically released from competing vegetation. The negative influence of age on aspen is probably a result of aspen growing out of the size class represented in this study. A separate analysis indicated that about 20 percent of the basal area and density of trees (greater than 1 inch d.b.h.) in the older plantations was attributable to deciduous hardwoods, mainly aspen and maple.

Aspen is a very common species and forest type throughout the Lake States (Brinkman and Roe 1975) and northeastern Minnesota (Grigal and Ohmann 1975, Ohmann and Ream 1971). It was recorded in 64 percent of the plantations studied here. Aspen is unique in that almost all stands originate as suckers that arise from existing root systems (Brinkman and Roe 1975). Aspen is an intolerant pioneer species that cannot reproduce successfully under its own shade. However, if aspen trees are present in the canopy, they can continue to produce suckers that serve as a reserve of aspen to regenerate a site after fire or logging. Aspen grows on a wide range of sites, from infertile sands to waterlogged mineral soils and peats (Brinkman and Roe 1975). Aerially applied 2,4-D herbicide during mid-July to mid-August will kill existing aspen trees and sprouts but will result in excellent resuckering the following year (Perala 1977). Controlling aspen when establishing a conifer plantation requires heavy mechanical disturbance or a herbicide site preparation, along with later successive herbicide or manual plantation releases (Perala 1977).

Aspen biomass was negatively associated with plantation age, with least biomass in the oldest plantations. Several factors may account for this trend: (1) the capability of aspen (a tree) to grow beyond the size-class category in this study (≥1 inch d.b.h.), (2) aspen shaded out by the conifers in older plantations, (3) fewer herbicide or release applications applied to younger plantations, increasing likelihood of resprouts, and (4) a positive association with rock-rake site preparation which was not practiced until 1960.

Prunus pensylvanica

Pin cherry was measured in 31 plantations and represented in all treatment categories. None of the treatment combinations was statistically significant. PREP explained 22 to 23 percent of the variation in biomass, followed by YEAR (18 percent), SPECIES (7 percent), and RELEASE (3 to 5 percent).

Above-average pin cherry biomass was associated with plantations between 5 and 25 years old that had been prepared for planting to pine by disk or rock-rake methods and later manually released from competing vegetation. Treatment categories associated with below-average pin cherry biomass were: (1) the very young plantations; (2) the oldest plantations that had undergone no site preparation before planting and no later release from competing vegetation; and (3) plantations where chemicals had been used to prepare the site for planting spruce.

Except for the lower biomass found in the 1- to 5-year-old plantations (where pin cherry was encountered in only one of the four plantations sampled) and the relatively high biomass with chemical release treatment, the distribution of pin cherry is consistent with what is known of its growth habits and response to management practices. Pin cherry is a common, fast-growing, short-lived, intolerant pioneer species of boreal forest ecosystems that declines about 25 to 35 years after disturbance (Marks 1974, Fulton 1974). Pin cherry usually becomes established after the logging of a mature forest. It grows from buried seed remaining in the forest floor from prior colonization or from prior dissemination by birds or small mammals (Marks 1974). Pin cherry is a common understory shrub in conifer plantations of northeastern Minnesota (Peek *et al.* 1976). It is very susceptible to 2,4-D or 2,4,5-T herbicides (Fulton 1974).

Prunus virginiana

Chokecherry was tallied in only 15 plantations but was represented in all treatment categories. None of the treatment combinations explained a statistically significant amount of the variation in any of the biomass classes. YEAR explained from 28 to 3[illegible] percent of the variation in biomass, followed by SPECIES (25 to 28 percent), PREP (18 to 22 percent), and RELEASE (9 to 10 percent).

Above-average biomass was associated with 5- to 10-year-old plantations that had been prepared by chemical treatment before planting spruce and older plantations that had received only manual release or where no release was recorded.

Chokecherry grows in a wide variety of soils and habitats throughout much of North America (Vilkitis 1974). It grows best in rich, well-drained, moist soil with adequate sunlight, but it is competitive and tolerant of shade and drought (Vilkitis 1974). Chokecherry is found commonly throughout northeastern Minnesota (Lakela 1965). The shrub was recorded in only 28 percent of the plantations of this study, and in only 25 percent of 33-year-old post-fire jack pine stands in an earlier study (Ohmann *et al.* 1973). Chokecherry reproduces by seed, but it also can sprout prolifically (Vilkitis 1974). The shrub may be somewhat resistant to both D and T herbicides (USDA 1961), but it is more susceptible to 2,4,5-T than to 2,4-D. For example, it was found in control plots but not in aerially treated (2,4,5-T herbicide) hardwood plots in northern Michigan (Gysel 1957).

This intermediate susceptibility to herbicides may explain the ambiguous result of more chokecherry biomass found in plantations prepared for planting by herbicide treatment and in older plantations receiving no herbicide release.

Rosa acicularis

Wild, prickly rose was represented in all treatment categories and recorded in 48 plantations. The treatment combinations YEAR-PREP-RELEASE and YEAR-SPECIES-RELEASE explained a significant amount of the variation in rose biomass. YEAR explained 17 to 19 percent of the variation in LEAF, TWIG, and STEM biomass; PREP explained 7 to 10 percent; SPECIES explained 7 to 9 percent; and RELEASE explained 5 percent.

Above-average biomass values were associated with 5- to 15-year-old plantations on sites that had been prepared by rock-raking, planted to a combination of pine and spruce, and later released from competition by manual plus chemical methods. Lower than average biomass values were associated with both the youngest and oldest plantations and with plantations that had been chemically prepared for planting to spruce.

Wild prickly rose is a circumboreal species that grows on a broad range of sites. It is common in conifer forests (Rosendahl 1955) and abundant as a successional species on disturbed areas (Densmore and Zasada 1977). After rose is established by seed, it can spread over wide areas vegetatively by rhizomes (Densmore and Zasada 1977). Because the degree of disturbance is important, rose was more abundant in nonscarified than in scarified conifer regeneration plots in interior Alaska (Zasada and Grigal 1978). In this case, the forest floor organic layers were totally removed by scarification, while there was rose vegetative reproduction from rhizomes on the relatively undisturbed organic layers of the nonscarified plots[1]. Rose is resistant to 2,4-D herbicide (Benzie 1977) but is susceptible to 2,4,5-T herbicide applied in May or June (Smithberg and Gill 1974). Rose was absent from northern Michigan plantations where 2,4,5-T herbicide was aerially applied (Gysel 1957).

The results of this study are generally consistent with known rose growth habits and response to management practices. More biomass was associated with sites prepared by rock-raking and those plantations treated by a manual plus chemical plantation release. If the herbicide was 2,4-D or if it was a D-T mixture but not effectively applied (applied in August), more biomass would occur. Manual release might involve severing some rose aerial stems that would produce more sprouts. More biomass following rock-raking as a site preparation treatment would not be likely unless the scraping did not remove all of the organic forest floor. Lower biomass would be associated with plantations prepared for planting by chemical treatment if, as is probable for site preparation purposes, the treatment was a 2,4-D and 2,4,5-T herbicide mixture applied in early summer.

Rubus strigosus

Raspberry was represented in all treatment categories and recorded in 51 sample plantations. The treatment combinations YEAR-SPECIES-RELEASE, and YEAR-PREP-RELEASE explained a significant amount of the variation in raspberry LEAF, TWIG, and WOOD biomass. YEAR explained from 36 to 44 percent of the biomass variation, followed by PREP (22 to 27 percent), RELEASE (16 to 17 percent), and SPECIES (7 to 8 percent).

Above-average biomass was associated with sites that had been chemically prepared for planting to spruce; and sites that were prepared by rock-raking and later chemically released. Below-average values were associated with older plantations with no site preparation and no later plantation release record.

These results are fully consistent with what is known about raspberry growth habits and the species' response to management practices. Raspberry is common in the forest types of this region (Rosendahl 1955). The species can reproduce from seeds, layers, sprouts, and underground stems (Core 1974). It grows better in partial shade than in full sunlight and can be rejuvenated by partial removal of overhead shade or deep cultivation (Core 1974). Scarification plots contained more raspberry than nonscarified conifer regeneration plots in interior Alaska (Zasada and Grigal 1978). Raspberry is resistant to 2,4-D herbicide (Benzie 1977). More raspberry biomass was found in younger plantations where herbicide was used to prepare sites for planting to spruce, where sites were rock-raked, and where it was used to release planted conifers. These practices reduce overhead shade but do not kill the resistant raspberry unless a combination of 2,4-D and 2,4,5-T is used. Management practices involving herbicides resulted in an increase in raspberry cover in Itasca State Park, Minnesota (Hansen *et al.* 1974). YEAR was the most important treatment. There was less raspberry biomass in older plantations where the ground was not disturbed before planting and where no release treatment was later applied to remove overhead shade.

Salix spp.

Willow was recorded in 24 plantations and was represented in all treatment categories except the youngest (1- to 5-year-old) plantations. None of the treatments explained a significant amount of the variation in biomass. In the case of LEAF and WOOD, RELEASE explained 23 and 24 percent of the variation in biomass, PREP 18 percent, YEAR 14 and 15 percent, and SPECIES 1 percent. In the case of TWIG, YEAR explained 31 percent, RELEASE 18 percent, PREP 18 percent, and SPECIES 2 percent.

Above-average biomass was associated with the oldest plantations that had received a disk treatment or no preparation before planting pine and that were later released by manual plus chemical or chemical methods. Below-average willow biomass was associated with: (1) younger plantations, (2) plantations that had received rock-rake or chemical site preparation (those planted to spruce), and (3) older plantations that had been given a manual release or where no release was recorded. To generalize, willow LEAF, TWIG, and STEM biomass was greatest in plantations receiving the least site preparation and the most release; willow biomass was lowest in plantations receiving the most site preparation and the least release.

Willows comprise a widely distributed genus with about 80 species throughout North America (Rosendahl 1955). At least 3 willow species grow in the study plantations: bebb willow (*S. bebbiana),* pussy willow (*S. discolor),* and upland willow (*S. humilis)* (Peek *et al.* 1976). Willows reproduce by seed, suckers, sprouts, and root shoots; are short-lived; and do best in good soils and full sunlight (Rawson 1974). Bebb willow grows both in moist and dry places; pussy willow is commonly found in swamps and other wet places, but it also grows well on dry soils; and upland willow is common on dry soils (Grimm 1957). Willows are susceptible to foliage application of 2,4-D and 2,4,5-T herbicides (Rawson 1974); however, they may resprout from the roots and stem base the season after treatment (USDA 1961). For example, Gysel (1957) found willow in both check and treatment plots after 2,4,5-T herbicide was aerially applied in northern Michigan.

More willow biomass associated with plantations receiving chemical release is consistent with the species' ability to reproduce vegetatively following such treatment.

CONCLUSIONS

Most of the responses to silvicultural practic found through this study are consistent with the e ological requirements of the species, at least to tl extent that their requirements have been doc mented. The silvicultural goal of successful esta lishment and regeneration of conifer stands was m for these plantations, yet the stands contained tε shrub layers similar to those in conifer stands nε urally regenerated after disturbance. The shrub la ers were also similar to those found in several m ture conifer forest communities in the area. N surprisingly, the study plantations contained le shrub layer biomass than did either regenerating mature aspen stands on better sites.

The effect of a persistent shrub layer on the lo term growth and yield of the planted conifers is relevant to the goal of successful re-establishm of the stand (thinning was not included in the stud The presence of a persistent shrub layer is, howe very important to the suitability of these plantati as wildlife habitat. Because a persistent shrub la adds to both species and structural diversity, i important not only to animals commonly though as browsers (deer, moose, and hare), but to inve brate browsers and to many birds as well (Pro 1979).

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APPENDIX

This Appendix presents the results of the ANOVAs and Multiple Classification Analysis (fig. 1). It also includes more detailed tabular information on species biomass by treatment (Appendix tables 4-7).

Of the 96 three-way ANOVAs conducted, 38 LEAF, TWIG, or WOOD cases were significant at the $p = \geqslant 0.10$ level for one or more sources of variation: model, main effect, independent variable 1, independent variable 2, independent variable 3, overall interaction, interaction between variable 1 and 2, interaction between variables 1 and 3, and interaction between variables 2 and 3 (Appendix table 8). ANOVA main effects were significant at $p = \geqslant 0.10$ most often for YEAR-SPECIES-RELEASE with 4 times each for LEAF, TWIG, and WOOD; for YEAR-RELEASE-PREP with 3 times each for LEAF, TWIG, and WOOD; and for YEAR-PREP-SPECIES with 2 LEAF, 1 TWIG, and 2 WOOD instances (Appendix table 8). The treatments as individual sources of significant variation (as variables 1, 2, or 3 listed in the combination) showed YEAR to be most important with significant F-ratios for 9 LEAF, 11 TWIG, and 10 WOOD instances. PREP was significant once for LEAF and WOOD; SPECIES was significant once for TWIG and twice each for LEAF and WOOD; and RELEASE was significant for 2 LEAF, 1 TWIG, and 2 WOOD instances. Overall interaction effect was significant in YEAR-RELEASE-PREP twice each for LEAF, TWIG, and WOOD; YEAR-SPECIES-RELEASE was significant in 2 LEAF, 1 TWIG, and 3 WOOD instances; and YEAR-PREP-SPECIES was significant once for LEAF and WOOD. Interaction between YEAR and PREP was significant twice each for LEAF and WOOD and once for TWIG; interaction between YEAR and RELEASE was significant 7 times for LEAF, 5 times for TWIG, and 6 times for WOOD. PREP-RELEASE and YEAR-SPECIES interactions were significant once each for LEAF and WOOD, and SPECIES-RELEASE was significant once each for LEAF, TWIG, and WOOD (Appendix table 8).

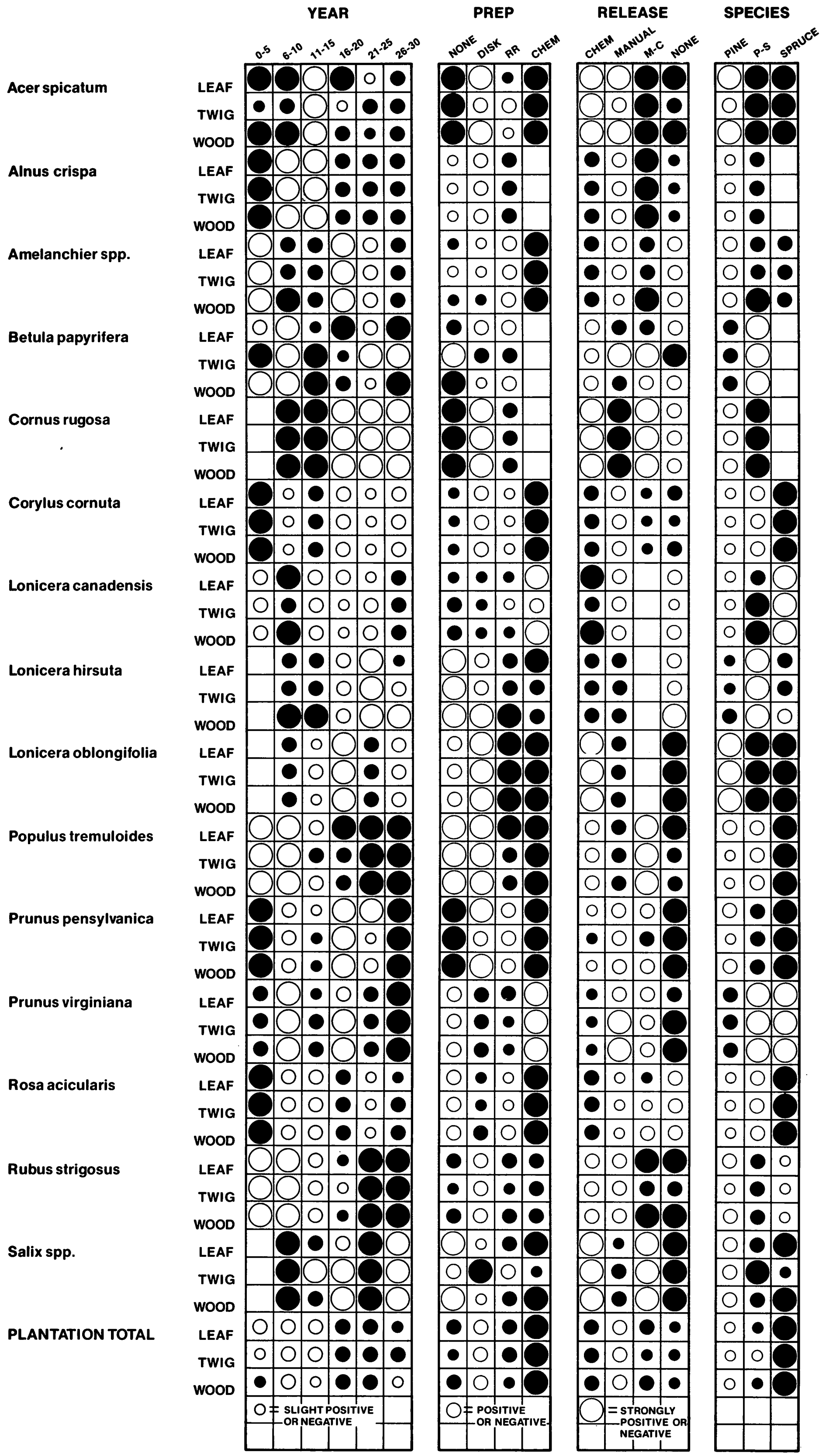

Figure 1.—*Diagrammatic representation of classification analysis results depicting the influence of silvicultural treatments on the major tall shrub and deciduous tree (under 1-inch d.b.h.) species in conifer plantations near Isabella, Minnesota. Shaded circles represent a negative influence and open circles represent a positive influence.*

Table 4.--Species and shrub layer total mean LEAF, TWIG, and WOOD biomass, standard error of the mean, and number of plantations for each establishment-period (YEAR) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the p=0.05 probability level[1/]

LEAF

Species	0-5 Years			6-10 Years			11-15 Years			16-20 Years			21-25 Years			26-30 Years			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	Pounds/acre	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Acer rubrum				0.2	--	1	44.7	44.2	2	39.8	34.3	3	7.2	7.2	2					
Acer spicatum	22.0	11.4	3	18.1	9.2	3	36.6	36.5	2	8.1	3.5	2	17.2	9.4	4	36.7	--	1	0.1745	0.966
Alnus crispa	.3	--	1	251.6	110.5	4	110.7	33.6	7	52.9	26.6	7	129.8	43.3	7	83.8	21.3	8	6.0403	.001
Alnus rugosa													31.4	--	1					
Amelanchier spp.	22.5	--	1	10.5	4.8	9	15.5	5.2	9	26.1	5.6	7	25.8	8.3	8	26.8	9.7	9	1.7077	.157
Betula papyrifera	.9	--	1	7.1b	2.0	3	.7ab	.1	6	.7ab	.4	3	2.8ab	1.4	3	.3a	.1	3	2.8782	.058
Cornus rugosa				1.6	--	1	36.6	24.6	5	24.4	2.0	2	4.2	2.9	2	12.0	6.2	3	.4169	.792
Cornus stolonifera				23.2	--	1														
Corylus cornuta	47.9	24.9	3	78.5	31.3	8	85.4	21.2	13	95.3	17.0	9	84.6	66.5	8	45.0	31.8	9	1.4362	.230
Lonicera canadensis	2.4	--	1	1.2	.4	5	3.2	1.2	5	1.7	.7	5	2.7	1.2	5	2.7	1.4	5	.3934	.848
Lonicera dioica				.8	--	1														
Lonicera hirsuta				.7	.2	4	1.6	.7	3	2.1	.8	3	4.7	--	1	1.9	--	1	.9726	.479
Lonicera oblongifolia				.3	.2	4	2.1	1.9	4	.4	.2	2	.1	.1	2	.8	.4	6	1.5737	.240
Lonicera villosa				4.6	--	1	1.0	--	1							.7	--	1		
Populus balsamifera							5.6	--	1	.8	--	1	.1	--	1					
Populus tremuloides	257.3b	51.8	3	27.0ab	10.9	9	32.7ab	8.5	9	24.4ab	11.2	6	1.0a	.9	3	.8a	.6	4	4.5879	.004
Prunus pensylvanica	.6	--	1	14.0	5.7	6	8.8	3.3	10	11.9	7.4	4	9.6	2.8	4	5.1	4.3	6	1.0943	.388
Prunus virginiana	11.5	6.5	2	18.7	9.6	3	8.7	1.2	3	17.8	5.4	3	7.2	3.7	3	5.5	--	1	.8483	.549
Rhamnus alnifolia																15.1	--	1		
Ribes hirsuta																.1	--	1		
Ribes spp.				2.5	2.4	2				.1	--	1				.2	--	1		
Rosa acicularis	1.0	.9	2	6.9	2.5	9	9.0	2.5	12	5.8	2.2	8	5.3	1.1	8	4.1	.7	9	1.6749	.162
Rosa blanda				.2	--	1	3.3	1.2	3	.6	--	1				3.6	--	1		
Rubus parviflorus							55.3	--	1											
Rubus strigosus	58.6b	10.5	4	26.0b	6.9	9	23.4b	11.8	12	16.2ab	9.8	9	6.6a	4.5	8	4.9a	1.7	9	5.3600	.001
Salix spp.				9.1	5.4	7	25.6	16.8	5	47.5	34.0	4	4.9	4.5	3	46.2	5.6	5	.8256	.525
Sorbus americana				.1	--	1	5.4	--	1				2.1	--	1					
Viburnum rafinesquianum													8.3	--	1					
Plantation total shrub layer	311.2	91.2	4	88.1	90.3	9	66.0	43.8	13	48.4	39.0	9	24.9	98.7	9	96.7	39.3	9	.2183	.953

(Table 4 continued on next page)

(Table 4 continued)

TWIG

Species	0-5 Years Mean	SE	N	6-10 Years Mean	SE	N	11-15 Years Mean	SE	N	16-20 Years Mean	SE	N	21-25 Years Mean	SE	N	26-30 Years Mean	SE	N	ANOVA F Ratio	Proba-bility
	Pounds/acre																			
Acer rubrum				3.1	--	1	34.5	30.6	2	22.3	19.2	3	17.5	17.3	2					
Acer spicatum	26.4	12.5	3	8.3	2.8	3	14.9	14.4	2	10.1	3.7	2	5.3	1.7	4	7.0	--	1	0.3356	0.879
Alnus crispa	.3	--	1	78.5	34.3	4	38.6	13.1	7	16.1	6.8	7	35.1	9.6	7	23.4	5.4	8	4.8735	.002
Alnus rugosa													31.5	--	1					
Amelanchier spp.	6.2	--	1	2.9	1.3	9	4.4	1.4	9	7.3	1.5	7	7.0	2.1	8	7.4	2.7	9	1.6725	.166
Betula papyrifera	.1	--	1	2.7b	1.4	3	.1a	.1	6	.4ab	.3	3	2.3ab	2.2	3	.1ab	.1	3	3.1529	.044
Cornus rugosa				.4	--	1	7.7	5.1	5	5.2	.3	2	.9	.6	2	2.5	1.2	3	.4119	.796
Cornus stolonifera				3.6	--	1														
Corylus cornuta	11.2	6.0	3	18.8	7.5	8	20.5	4.6	13	23.5	4.0	9	41.6	14.3	8	33.7	7.0	9	1.5264	.201
Lonicera canadensis	1.0	--	1	.4	.2	5	1.2	.4	5	.5	.3	5	.9	.4	5	.8	.4	5	.6090	.694
Lonicera dioica				.3	--	1				.3	--	1								
Lonicera hirsuta				.3	.1	4	.5	.3	3	.9	.4	3	1.8	--	1	.9	--	1	.9152	.505
Lonicera oblongifolia				.2	.1	4	1.3	1.2	4	.2	.1	2	.1	.1	2	.4	.3	6	1.6277	.226
Lonicera villosa				.7	--	1	.4	--	1							.2	--	1		
Populus balsamifera							1.1	--	1				.1	--	1					
Populus tremuloides	28.3c	6.6	3	3.5bc	1.2	9	4.2bc	1.2	9	3.2bc	1.6	6	.3ab	.2	3	.3a	.1	4	5.5455	.001
Prunus pensylvanica	.5	--	1	4.1	1.5	6	2.1	.5	10	3.9	1.9	4	2.1	.5	4	1.2	.7	6	1.1099	.380
Prunus virginiana	2.5	1.7	2	4.0	2.5	3	1.4	.2	3	4.5	2.0	3	1.6	.9	3	1.2	--	1	.7251	.622
Rhamnus alnifolia																3.3	--	1		
Ribes hirsuta																.1	--	1		
Ribes spp.				1.1	1.1	2				.1	--	1				.1	--	1		
Rosa acicularis	.4	.4	2	2.9	1.1	9	3.9	1.1	12	2.5	1.0	8	2.2	.5	8	1.8	.4	9	1.8337	.127
Rosa blanda				.2	--	1	2.0	.7	3	.4	--	1				2.1	--	1		
Rubus parviflorus							70.2	--	1											
Rubus strigosus	14.6b	2.9	4	7.5b	1.8	9	5.6b	1.8	12	4.3ab	2.1	9	1.8a	1.1	8	1.4a	.4	9	7.1148	.001
Salix spp.				1.1	.6	7	3.1	2.1	5	5.7	4.1	4	.6	.5	3	5.5	3.1	5	2.1835	.110
Sorbus americana				.1	--	1	2.0	--	1				.6	--	1					
Viburnum rafinesquianum				.9	--	1														
Plantation total shrub layer	65.9	22.4	4	78.8	26.1	9	77.1	15.7	13	67.9	11.5	9	87.2	23.7	9	71.9	9.7	9	.1479	.980

(Table 4 continued on next page)

(Table 4 continued)

WOOD

Species	0-5 Years Mean	0-5 Years SE	0-5 Years N	6-10 Years Mean	6-10 Years SE	6-10 Years N	11-15 Years Mean	11-15 Years SE	11-15 Years N	16-20 Years Mean	16-20 Years SE	16-20 Years N	21-25 Years Mean	21-25 Years SE	21-25 Years N	26-30 Years Mean	26-30 Years SE	26-30 Years N	ANOVA F Ratio	ANOVA Probability
	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	Pounds/acre	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Acer rubrum				1.3	--	1	334.9	330.4	2	275.7	267.6	3	54.6	54.6	2					
Acer spicatum	347.5	178.0	3	199.0	73.3	3	383.7	380.5	2	140.0	55.1	2	153.2	67.8	4	304.4	--	1	0.1823	0.962
Alnus crispa	1.3	--	1	2085.6	917.1	4	876.6	251.6	7	447.7	238.0	7	1176.7	420.8	7	743.2	196.3	8	6.4638	.001
Alnus rugosa													311.8	--	1					
Amelanchier spp.	167.9	--	1	75.6	40.1	9	108.7	43.2	9	182.2	47.8	7	255.8	107.5	8	224.8	90.2	9	1.9014	.118
Betula papyrifera	2.8	--	1	67.8b	29.1	3	2.0ab	.4	6	7.8ab	6.7	3	34.3ab	32.1	3	.5a	.3	3	2.3526	.099
Cornus rugosa				4.1	--	1	150.3	109.8	5	87.8	7.5	2	13.5	10.3	2	51.5	27.6	3	.4210	.790
Cornus stolonifera													124.9	--	1					
Corylus cornuta	365.4	192.4	3	605.8	240.8	8	659.0	154.9	13	747.7	128.9	9	1371.3	480.6	8	1097.2	232.4	9	1.4901	.212
Lonicera canadensis	15.7	--	1	7.8	2.7	5	20.5	7.3	5	9.8	4.1	5	15.3	6.4	5	14.1	7.2	5	.5088	.766
Lonicera dioica				2.0	--	1				2.2	--	1								
Lonicera hirsuta				1.3	.4	4	2.4	1.2	3	18.1	14.0	3	11.7	--	1	15.1	--	1	.7849	.570
Lonicera oblongifolia				.8	.6	4	6.4	5.6	4	1.1	.6	2	.1	.1	2	2.3	1.2	6	1.5795	.238
Lonicera villosa				17.1	--	1	6.2	--	1							3.7	--	1		
Populus balsamifera							49.3	--	1				1.2	--	1					
Populus tremuloides	1414.9c	311.7	3	169.3bc	61.2	9	203.6bc	50.0	9	153.8bc	74.3	6	9.5	7.6	3ab	9.0a	5.4	4	5.3081	.002
Prunus pensylvanica	7.2	--	1	128.5	51.6	6	76.2	26.9	10	112.4	68.6	4	84.3	23.5	4	44.2	35.9	6	1.1120	.380
Prunus virginiana	59.4	42.4	2	95.9	60.8	3	31.7	4.4	3	113.4	50.2	3	39.5	22.2	3	29.0	--	1	.7167	.627
Rhamnus alnifolia																86.9	--	1		
Ribes hirsuta																.4	--	1		
Ribes spp.				22.8	22.7	2				.4	--	1				.8	--	1		
Rosa acicularis	2.1a	2.0	2	17.8ab	6.7	9	24.9b	6.9	12	16.0ab	7.0	8	13.0ab	2.8	8	10.5ab	2.5	9	1.9839	.101
Rosa blanda				.4	--	1	11.4	5.4	3	1.2	--	1				13.2	--	1		
Rubus parviflorus							70.2	--	1											
Rubus strigosus	89.0b	16.2	4	38.8b	10.3	9	40.6b	18.4	12	24.4ab	14.9	9	9.9a	6.9	8	7.4a	2.5	9	5.1676	.001
Salix spp.				55.7	37.5	7	230.5	175.0	5	481.3	381.2	4	28.3	27.2	3	410.1	231.2	5	.8485	.572
Sorbus americana				.2	--	1	45.7	--	1				12.4	--	1					
Viburnum rafinesquianum													32.4	--	1					
Plantation total shrub layer	1722.4	687.2	4	2043.5	730.3	9	1768.7	306.6	13	1837.7	238.7	9	2589.4	828.0	9	2333.7	318.1	9	.5480	.739

1/Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.

Table 5.--Species and plantation shrub layer total mean LEAF, TWIG, and WOOD biomass, standard error of the mean, and number of plantations for each site-preparation (PREP) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the p=0.05 probability level[1/]

LEAF

Species	None			Disk			Rockrake			Chemical			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	Pounds/acre													
Acer rubrum	3.9	3.5	4	66.2	32.9	3				0.2	--	1		
Acer spicatum	30.0	22.1	3	21.0	7.9	5	19.5	6.9	6	3.4	--	1	0.3178	0.812
Alnus crispa	88.5	20.3	7	90.0	23.0	17	158.2	53.3	10				.1741	.841
Alnus rugosa	31.4	--	1											
Amelanchier spp.	24.6	9.0	9	23.8	4.7	19	17.0	4.5	12	2.7	1.1	3	1.9857	.132
Betula papyrifera	1.3	.8	5	11.1	.5	7	3.4	1.5	7				1.6443	.224
Cornus rugosa	6.2	5.1	4	40.7	23.3	5	12.5	6.7						
Cornus stolonifera										26.0	--	1		
Corylus cornuta	110.0ab	33.2	10	142.0b	27.8	21	83.8ab	16.7	17	6.7a	.7	2	2.6895	.057
Lonicera canadensis	2.1	1.1	4	2.4	.7	11	2.4	.7	9	1.4	.6	2	.0259	.994
Lonicera dioica				.8	--	1	.8	--	1					
Lonicera hirsuta	2.9	--	1	2.5	.7	5	.9	.3	5	.4	--	1	1.8857	.210
Lonicera oblongifolia	1.4	1.2	6	.8	.4	6	.3	.2	5	.1	--	1	1.0417	.405
Lonicera villosa	.7	--	1				2.8	1.9	2					
Populus balsamifera	.1	--	1				5.6	--	1					
Populus tremuloides	12.9	8.4	7	22.5	8.1	10	79.1	28.5	14	13.3	6.6	3	1.5956	.211
Prunus pensylvanica	2.6	1.6	6	9.8	3.4	11	12.8	3.4	13	.2	--	1	2.6862	.066
Prunus virginiana	11.2	2.3	2	11.2	3.3	7	9.5	2.3	5	38.0	--	1	1.0395	.413
Rhamnus alnifolia	15.1	--	1											
Ribes hirsuta				.1	--	1								
Ribes spp.				.2	.1	2				2.5	2.4	2		
Rosa acicularis	6.5	1.9	10	5.2	1.1	19	8.0	2.0	16	2.0	1.2	3	1.6219	.198
Rosa blanda	3.6	--	1	2.3	1.7	2	2.1	1.5	3					
Rubus parviflorus				55.3	--	1								
Rubus strigosus	5.7	2.1	10	12.4	4.8	20	34.9	8.8	18	31.9	13.1	3	4.7234	.006
Salix spp.	49.7	24.6	5	34.0 1	6.9	9	7.5	4.6	8	6.8	6.4	2	1.4070	.270
Sorbus americana	3.7	1.7	2				.1	--	1					
Viburnum rafinesquianum				8.3	--	1								
Plantation total shrub layer	240.3	52.4	11	316.9	43.8	21	310.3	46.3	18	83.2	7.3	3	3.0034	.039

(Table 5 continued on next page)

(Table 5 continued)

TWIG

Species	None Mean	None SE	None N	Disk Mean	Disk SE	Disk N	Rockrake Mean	Rockrake SE	Rockrake N	Chemical Mean	Chemical SE	Chemical N	ANOVA F Ratio	ANOVA Probability
	Pounds/acre													
Acer rubrum	10.4	8.1	4	66.2	32.9	3				3.1	--	1		
Acer spicatum	12.2	8.7	3	8.2	1.4	5	16.8	7.2	6	4.0	--	1	0.1696	0.915
Alnus crispa	26.0	5.9	7	25.0	5.4	17	52.3	17.2	10				.2540	.777
Alnus rugosa	31.5	--	1											
Amelanchier spp.	6.8	2.4	9	6.6	1.2	19	4.7	1.2	12	.8	.4	3	2.0075	.129
Betula papyrifera	1.4	1.3	5	.2	.1	7	1.2	.8	7				.2213	.804
Cornus rugosa	1.3	1.1	4	8.5	4.8	5	2.7	1.4	4				2.7222	.114
Cornus stolonifera										3.6	--	1		
Corylus cornuta	25.1ab	7.2	10	33.3b	6.0	21	20.3ab	3.9	17	1.9a	.3	2	2.7763	.052
Lonicera canadensis	.7	.4	4	.7	.3	11	1.0	.3	9	.5	.2	2	.0942	.962
Lonicera dioica				.3	--	1	.3	--	1					
Lonicera hirsuta	1.0	--	1	1.1	.3	5	.3	.1	5	.2	--	1	1.6565	.252
Lonicera oblongifolia	.9	.8	6	.4	.3	6	.2	.1	5	.1	--	1	1.1089	.379
Lonicera villosa	.2	--	1				.5	.2	2					
Populus balsamifera	.1	--	1				1.1	--	1					
Populus tremuloides	1.7	1.0	7	2.9	1.1	10	9.2	3.1	14	1.9	1.0	3	1.8982	.151
Prunus pensylvanica	.8	.3	6	2.6	.8	11	3.4	.8	13	.3	--	1	2.5732	.075
Prunus virginiana	2.3	1.0	2	2.6	1.0	7	1.8	.6	5	8.9	--	1	.8378	.501
Rhamnus alnifolia	3.3	--	1											
Ribes hirsuta				.1	--	1								
Ribes spp.				.1	.1	2				1.1	1.1	2		
Rosa acicularis	2.8	.8	10	2.2	.5	19	3.5	.9	16	.9	.5	3	1.4843	.232
Rosa blanda	2.1	--	1	1.3	.9	2	1.2	1.0	3					
Rubus parviflorus				70.2	--	1								
Rubus strigosus	1.7	.5	10	3.4	1.1	20	8.3	1.7	18	8.7	3.1	3	5.9434	.002
Salix spp.	6.0	2.9	5	4.1	2.1	9	.9	.5	8	.8	.8	2	1.4211	.266
Sorbus americana	1.2	.6	2				.1	--	1					
Viburnum rafinesquianum				.9	--	1								
Plantation total shrub layer	65.7	16.2	11	84.7	11.6	21	80.9	13.5	18	21.8	1.3	3	2.7858	.051

(Table 5 continued on next page)

(Table 5 continued)

WOOD

Species	None			Disk			Rockrake			Chemical			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	Pounds/acre													
Acer rubrum	30.1	26.4	4	495.4	246.5	3				1.3	--	1		
Acer spicatum	314.3	230.8	3	303.8	48.8	5	264.4	96.8	6	56.6	--	1	0.2755	0.842
Alnus crispa	771.8	180.3	7	799.4	218.6	17	1280.2	437.3	10				.1670	.847
Alnus rugosa	311.8	--	1											
Amelanchier spp.	203.6	86.0	9	197.1	52.0	19	129.8	39.3	12	12.9	5.2	3	1.8423	.156
Betula papyrifera	21.0	19.4	5	4.4	2.9	7	30.0	17.3	7				1.0956	.358
Cornus rugosa	26.4	23.1	4	168.2	104.6	5	41.4	22.7	4				2.6990	.116
Cornus stolonifera										124.9	--	1		
Corylus cornuta	822.0ab	240.4	10	1080.0b	201.5	21	651.2ab	127.2	17	56.6a	7.1	2	2.7413	.054
Lonicera canadensis	12.2	6.1	4	13.4	4.1	11	15.5	4.6	9	8.7	3.3	2	.0599	.980
Lonicera dioica				2.0	--	1	2.0	--	1					
Lonicera hirsuta	4.6	--	1	16.2	7.8	5	1.4	.6	5	1.0	--	1	1.3110	.336
Lonicera oblongifolia	4.4	3.7	6	2.4	1.2	6	1.0	.4	5	.1	--	1	1.0568	.399
Lonicera villosa	3.7	--	1				11.7	5.4	2					
Populus balsamifera	1.1	--	1				49.3	--	1					
Populus tremuloides	80.4	48.6	7	140.7	51.4	10	453.7	156.9	14	88.9	44.7	3	1.8766	.155
Prunus pensylvanica	23.6	13.9	6	88.3	30.1	11	113.6	29.1	13	1.9	--	1	2.7587	.062
Prunus virginiana	54.1	25.0	2	64.0	26.1	7	42.9	15.1	5	217.5	--	1	.8280	.505
Rhamnus alnifolia	86.9	--	1											
Ribes hirsuta				.4	--	1								
Ribes spp.				.5	.2	2				22.8	22.7	2		
Rosa acicularis	16.6	5.2	10	13.6	3.4	19	21.8	5.5	16	5.4	3.8	3	1.2490	.304
Rosa blanda	13.2	--	1	11.0	9.7	2	4.6	3.5	3					
Rubus parviflorus				70.2	--	1								
Rubus strigosus	8.5	3.0	10	18.7	7.3	20	53.1	13.6	18	48.0	19.8	3	4.5520	.007
Salix spp.	439.3	221.5	5	330.5	187.7	9	45.8	32.9	8	32.4	31.4	2	1.4041	.271
Sorbus americana	45.7	12.4	2				.2	--	1					
Viburnum rafinesquianum				32.4	--	1								
Plantation total shrub layer	1862.5a	439.3	11	2390.6a	353.0	21	2074.7a	360.6	18	370.1b	52.4	3	3.4705	.023

1/Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.

Table 6.--Species and plantation shrub layer total mean LEAF, TWIG, and WOOD biomass, standard error of the mean, and number of plantations for each release (RELEASE) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the p=0.05 probability level[1/]

LEAF

Species	Chemical			Manual			Manual-chemical			No record			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Proba-bility
	Pounds/acre													
Acer rubrum	.4	.2	2	40.9	34.0	3	88.8	--	1	1.1	.2	2		
Acer spicatum	29.9	15.2	4	25.1	6.7	7	.1	--	1	6.8	3.5	3	1.2235	0.347
Alnus crispa	125.1	48.1	7	120.3	31.3	16	39.2	4.3	2	94.6	37.9	9	.0668	.997
Alnus rugosa				31.4	--	1								
Amelanchier spp.	17.1	6.2	13	24.0	5.3	18	7.0	6.2	2	21.7	5.1	10	1.9715	.134
Betula papyrifera	2.6	1.8	5	2.3	1.0	8	.7	--	1	1.2	.5	5	.1555	.924
Cornus rugosa	16.6	7.4	3	10.1	3.9	7	132.8	--	1	12.6	10.9	2	1.2234	.356
Cornus stolonifera	23.2	--	1											
Corylus cornuta	59.9	17.3	15	128.5	19.1	20	105.3	53.0	3	144.8	45.8	12	1.5490	.215
Lonicera canadensis	1.2	.4	5	2.9	.6	15				1.9	.6	6	.7334	.491
Lonicera dioica	.8	--	1							.8	--	1		
Lonicera hirsuta	1.4	.5	6	2.1	1.3	3				1.9	.4	3	.4138	.673
Lonicera oblongifolia	2.7	2.5	3	.4	.3	10				.4	.3	5	.1530	.860
Lonicera villosa				.9	.2	2	4.6	--	1					
Populus balsamifera	5.6	--	1	.1	--	1								
Populus tremuloides	28.5	11.1	14	51.7	33.0	10	37.5	20.8	2	59.0	32.9	8	.9606	.424
Prunus pensylvanica	8.4	3.9	9	10.8	3.0	15	8.6	3.2	2	7.1	5.0	5	.4693	.706
Prunus virginiana	12.0	4.4	7	14.1	3.1	4	10.9	--	1	11.8	7.6	3	.4178	.744
Rhamnus alnifolia				55.3	--	1								
Ribes hirsuta				.1	--	1								
Ribes spp.	2.5	2.4	2	.2	--	1				.1	--	1		
Rosa acicularis	6.2	2.1	15	6.1	1.2	20	7.5	3.3	3	6.0	1.7	10	.8390	.480
Rosa blanda				3.1	1.2	3	3.9	--	1	.4	.2	2		
Rubus parviflorus							55.3	--	1					
Rubus strigosus	36.5ab	9.6	16	13.1a	4.9	20	12.9a	10.3	3	12.0b	5.3	12	3.3442	.027
Salix spp.	37.3	16.9	8	23.2	15.4	9	89.4	--	1	5.1	3.3	6	2.0205	.143
Sorbus americana	5.4	--	1	1.1	1.0	2								
Viburnum rafinesquianum	8.3	--	1											
Plantation total shrub layer	221.2	40.1	17	321.9	40.8	21	314.5	128.4	3	305.1	67.6	12	1.1482	.339

(Table 6 continued on next page)

(Table 6 continued)

TWIG

Species	Chemical			Manual			Manual-chemical			No record			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	Pounds/acre													
Acer rubrum	3.5	.4	2	31.8	17.5	3	65.1	--	1	3.1	.3	2		
Acer spicatum	21.5	7.8	4	10.6	4.8	7	.4	--	1	7.0	3.6	3	1.9206	0.185
Alnus crispa	40.9	16.4	7	36.8	9.8	16	12.2	4.4	2	25.8	8.3	9	.1279	.943
Alnus rugosa				31.5	--	1								
Amelanchier spp.	4.8	1.7	13	6.6	1.7	18	2.1	1.8	2	6.0	1.3	10	1.9794	.142
Betula papyrifera	1.2	1.1	5	1.1	.9	8	.1	--	1	.3	.2	5	.3409	.796
Cornus rugosa	3.6	1.6	3	2.1	.8	7	27.6	--	1	2.7	2.3	2	1.2226	.357
Cornus stolonifera	3.6	--	1											
Corylus cornuta	14.4	3.9	15	30.3	4.1	20	24.4	11.9	3	33.4	10.0	12	1.6760	.185
Lonicera canadensis	.4	.1	5	1.0	.2	15				.6	.2	6	1.0247	.375
Lonicera dioica	.3	--	1							.3	--	1		
Lonicera hirsuta	.5	.3	6	.7	.5	3				.7	.2	3	.4352	.660
Lonicera oblongifolia	1.7	1.6	3	.3	.2	10				.3	.2	5	.1220	.886
Lonicera villosa				.3	.1	2	.7	--	1					
Populus balsamifera	1.1	--	1	.1	--	1								
Populus tremuloides	3.7	1.2	14	6.5	4.0	10	4.8	2.1	2	6.3	3.1	8	.5879	.628
Prunus pensylvanica	2.2	1.0	9	2.9	.7	15	1.6	.8	2	2.1	1.1	5	.1727	.914
Prunus virginiana	2.4	1.1	7	3.0	.6	4	1.8	--	1	3.3	2.6	3	.3850	.766
Rhamnus alnifolia				3.3	--	1								
Ribes hirsuta				.1	--	1								
Ribes spp.	1.1	1.1	2	.1	--	1				.1	--	1		
Rosa acicularis	2.7	.9	15	2.6	.5	20	3.4	1.5	3	2.6	.8	10	.8198	.490
Rosa blanda				2.2	.7	3	2.2	--	1	.4	.2	2		
Rubus parviflorus							70.2	--	1					
Rubus strigosus	7.9	1.7	16	3.6	1.1	20	4.3	3.3	3	4.1	1.8	12	3.0553	.037
Salix spp.	4.5	2.1	8	2.8	1.9	9	10.8	--	1	.6	.4	6	1.5094	.243
Sorbus americana	2.0	--	1	.4	.4	2								
Viburnum rafinesquianum	.9	--	1											
Plantation total shrub layer	57.5	12.0	17	87.6	11.4	21	105.2	56.0	3	73.9	14.8	12	1.8328	.154

(Table 6 continued on next page)

(Table 6 continued)

WOOD

Species	Chemical Mean	Chemical SE	Chemical N	Manual Mean	Manual SE	Manual N	Manual-chemical Mean	Manual-chemical SE	Manual-chemical N	No record Mean	No record SE	No record N	ANOVA F Ratio	ANOVA Probability
	- - -	- - -	- - -	- - -	- - -	- - -	- - - Pounds/acre - - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Acer rubrum	2.8	1.4	2	306.7	254.3	3	665.6	--	1	8.1	1.6	2		
Acer spicatum	373.7	151.3	4	256.5	74.0	7	3.1	--	1	103.6	54.9	3	1.3393	0.312
Alnus crispa	1017.9	385.3	7	1026.3	261.2	16	325.8	5.7	2	844.1	366.4	9	.0562	.982
Alnus rugosa				311.8	--	1								
Amelanchier spp.	126.6	53.3	13	207.1	58.7	18	37.5	35.0	2	172.2	46.1	10	2.3298	.089
Betula papyrifera	26.0	23.6	5	21.2	13.4	8	2.3	--	1	8.7	4.9	5	.1570	.924
Cornus rugosa	55.6	25.3	3	37.5	15.2	7	583.9	--	1	49.7	45.6	2	1.1836	.369
Cornus stolonifera	124.9	--	1											
Corylus cornuta	462.9	128.3	15	981.9	138.6	20	796.2	391.9	3	1092.8	333.9	12	1.6234	.197
Lonicera canadensis	7.0	1.9	5	16.9	3.8	15				11.0	3.6	6	.8908	.424
Lonicera dioica	2.0	--	1							2.0	--	1		
Lonicera hirsuta	9.0	7.4	6	4.6	3.6	3				8.6	3.7	3	.5951	.572
Lonicera oblongifolia	8.1	7.6	3	1.4	.7	10				1.4	.8	5	.1420	.869
Lonicera villosa				4.9	1.2	2	17.1	--	1					
Populus balsamifera	49.3	--	1	1.1	--	1								
Populus tremuloides	174.2	63.2	14	314.6	196.2	10	229.2	105.0	2	317.9	159.9	8	.6632	.581
Prunus pensylvanica	74.2	33.8	9	97.0	26.8	15	74.8	28.5	2	64.2	42.9	5	.4318	.732
Prunus virginiana	58.6	26.8	7	72.6	15.4	4	40.1	--	1	82.7	65.3	3	.3738	.774
Rhamnus alnifolia				86.9	--	1								
Ribes hirsuta				.4	--	1								
Ribes spp.	22.8	22.7	2	.8	--	1				.4	--	1		
Rosa acicularis	16.6	5.8	15	15.5	3.2	20	23.5	11.2	3	16.0	5.6	10	.7495	.528
Rosa blanda				8.9	3.5	3	20.7	--	1	.9	.4	2		
Rubus parviflorus							70.2	--	1					
Rubus strigosus	55.8a	14.9	16	19.7b	7.4	20	19.1ab	15.3	3	17.7b	7.8	12	3.3138	.028
Salix spp.	367.0	195.1	8	176.7	129.2	9	916.4	--	1	26.7	18.1	6	2.1176	.130
Sorbus americana	45.7	--	1	1.9	1.6	2								
Viburnum rafinesquianum	32.4	--	1											
Plantation total shrub layer	1491.2	314.1	17	2426.2	310.6	21	2051.2	846.9	3	2222.2	580.1	12	2.0070	.125

1/Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.

Table 7.--Species and plantation shrub layer total mean LEAF, TWIG, and WOOD biomass, standard error of the mean, and number of plantations for each species planted (SPECIES) category for conifer plantations near Isabella, Minnesota. Means in a row followed by the same letter do not differ at the p=0.05 probability level1/

LEAF

Species	Pine Mean	Pine SE	Pine N	Pine & Spruce Mean	Pine & Spruce SE	Pine & Spruce N	Spruce Mean	Spruce SE	Spruce N	ANOVA F Ratio	ANOVA Probability
	- - -	- - -	- - -	- - -	- - -	Pounds/acre	- - -	- - -	- - -	- - -	- - -
Acer rubrum	36.6	35.9	4	26.1	21.1	3	0.2	--	1		
Acer spicatum	20.2	4.9	11	30.0	22.1	3	3.4	--	1	0.2471	0.785
Alnus crispa	120.8	25.2	26	73.9	21.1	8				.0633	.803
Alnus rugosa				31.4	--	1					
Amelanchier spp.	24.8	4.1	30	13.5	3.2	10	2.7	1.1	3	3.4174	.043
Betula papyrifera	2.1	.8	14	1.6	.8	5				.1061	.749
Cornus rugosa	13.2	3.7	9	39.9	31.4	4				.1890	.672
Cornus stolonifera							23.2	--	1		
Corylus cornuta	116.0	18.7	36	110.9	26.2	12	6.7	.7	2	2.8724	.067
Lonicera canadensis	2.5	.5	19	1.8	.9	5	1.4	.6	2	.0805	.932
Lonicera dioica	.8	.8	2								
Lonicera hirsuta	1.7	.4	10	2.9	--	1	.4	--	1	1.1279	.366
Lonicera oblongifolia	.6	.2	11	1.3	1.2	6	.1	--	1	1.3898	.279
Lonicera villosa	2.7	2.0	2	1.0	--	1					
Populus balsamifera	2.8	2.8	2								
Populus tremuloides	50.3	17.2	25	27.7	10.5	6	13.3	11.4	3	.0207	.980
Prunus pensylvanica	10.9	2.4	24	4.5	2.3	6	.2	--	1	1.0844	.352
Prunus virginiana	9.4	1.5	12	17.7	8.8	2	38.0	--	1	2.3458	.138
Rhamnus alnifolia	15.1	--	1								
Ribes hirsuta	.1	--	1								
Ribes spp.	.2	--	1	.1	--	1	2.5	2.4	2		
Rosa acicularis	6.1	1.1	34	7.7	2.1	11	2.0	1.2	3	2.3263	.109
Rosa blanda	2.9	1.4	3	1.9	1.1	3					
Rubus parviflorus				55.3	--	1					
Rubus strigosus	23.5	5.3	37	6.0	1.6	11	31.9	13.1	3	2.0072	.146
Salix spp.	28.8	11.2	17	24.9	16.9	5	6.8	6.4	2	.0549	.947
Sorbus americana	.1	--	1	3.7	1.6	2					
Viburnum rafinesquianum	8.3	--	1								
Plantation total shrub layer	311.6a	32.0	38	253.8ab	50.8	12	83.2b	7.3	3	3.2543	.047

(Table 7 continued) TWIG

Species	Pine			Pine & Spruce			Spruce			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Probability
	- - - - - - - - - -			- - - - Pounds/acre - - - -							
Acer rubrum	22.5	19.1	4	25.9	15.3	3	3.1	--	1		
Acer spicatum	12.8	4.1	11	12.2	8.7	3	4.0	--	1	0.2676	0.770
Alnus crispa	36.5	7.7	26	22.8	5.9	8				.0452	.833
Alnus rugosa				31.5	--	1					
Amelanchier spp.	6.9a	1.1	30	3.8ab	.9	10	.8b	.4	3	3.4666	.041
Betula papyrifera	.6	.4	14	1.6	1.3	5				.1733	.682
Cornus rugosa	2.8	.8	9	8.3	6.5	4				.1895	.672
Cornus stolonifera							3.6	--	1		
Corylus cornuta	27.2	4.1	36	26.3	5.8	12	1.9	.3	2	2.8590	.067
Lonicera canadensis	.9	.2	19	.6	.3	5	.5	.2	2	.1843	.833
Lonicera dioica	.3	.3	2								
Lonicera hirsuta	.7	.2	10	1.0	--	1	.2	--	1	.7010	.521
Lonicera oblongifolia	.4	.2	11	.9	.8	6	.1	--	1	1.4783	.259
Lonicera villosa	.4	.3	2	.4	--	1					
Populus balsamifera	.5	.5	2								
Populus tremuloides	6.0	2.0	25	3.5	1.2	6	1.9	1.0	3	.0229	.977
Prunus pensylvanica	2.7	.6	24	1.9	.7	6	.3	--	1	1.0575	.361
Prunus virginiana	1.9	.4	12	4.8	3.6	2	9.0	--	1	2.0474	.172
Rhamnus alnifolia	3.3	--	1								
Ribes hirsuta	.1	--	1								
Ribes spp.	.1	--	1	.1	--	1	1.1	1.1	2		
Rosa acicularis	2.6	.4	34	3.3	1.0	11	.9	.5	3	2.1162	.132
Rosa blanda	1.8	.9	3	1.1	.6	3					
Rubus parviflorus				70.2	--	1					
Rubus strigosus	5.7	1.1	37	1.9	.4	11	8.7	3.1	3	2.1858	.124
Salix spp.	3.5	1.3	17	3.0	2.1	5	.9	.9	2	.2128	.810
Sorbus americana	.1	--	1	1.2	.6	2					
Viburnum rafinesquianum	.9	--	1								
Plantation total shrub layer	79.0a	8.4	38	79.6a	18.4	12	21.8b	13	3	2.5502	.088

(Table 7 continued on next page)

(Table 7 continued)

WOOD

Species	Pine			Pine & Spruce			Spruce			ANOVA	
	Mean	SE	N	Mean	SE	N	Mean	SE	N	F Ratio	Proba-bility
	Pounds/acre										
Acer rubrum	273.8	268.5	4	196.2	158.4	3	1.3	--	1		
Acer spicatum	236.8	55.5	11	314.3	230.8	3	56.6	--	1	0.2774	0.762
Alnus crispa	1027.9	216.0	26	633.4	188.7	8				.0492	.826
Alnus rugosa				311.8	--	1					
Amelanchier spp.	205.9	42.4	30	95.7	22.7	10	12.9	5.2	3	3.1019	.056
Betula papyrifera	15.7	9.2	14	25.1	18.7	5				.8261	.376
Cornus rugosa	47.1	13.2	9	172.1	139.0	4				.2099	.656
Cornus stolonifera							124.9	--	1		
Corylus cornuta	819.9	8.5	36	849.7	192.2	12	56.6	7.1	2	2.8658	.067
Lonicera canadensis	14.9	3.1	19	10.5	5.1	5	8.7	3.3	2	.1382	.872
Lonicera dioica	2.0	2.0	2								
Lonicera hirsuta	8.8	4.5	10	4.6	--	1	1.0	--	1	.1550	.859
Lonicera oblongifolia	1.9	.6	11	4.2	3.8	6	.1	--	1	1.4133	.274
Lonicera villosa	10.3	6.8	2	6.2	--	1					
Populus balsamifera	25.2	24.2	2								
Populus tremuloides	292.6	96.0	25	167.9	59.8	6	88.9	44.7	3	.0152	.985
Prunus pensylvanica	97.3	21.0	24	42.5	21.4	6	1.9	--	1	1.1314	.337
Prunus virginiana	44.2	8.3	12	120.6	91.4	2	217.5	--	1	2.0350	.173
Rhamnus alnifolia	86.9	--	1								
Ribes hirsuta	.4	--	1								
Ribes spp.	.8	--	1	.4	--	1	22.8	22.7	2		
Rosa acicularis	16.1	2.9	34	20.6	6.3	11	5.4	3.8	3	1.7079	.193
Rosa blanda	8.4	4.0	3	8.0	6.3	3					
Rubus parviflorus				70.2	--	1					
Rubus strigosus	35.6	8.1	37	8.9	2.5	11	48.0	19.8	3	1.9290	.156
Salix spp.	258.9	113.8	17	227.5	176.0	5	32.4	31.4	2	.0380	.963
Sorbus americana	.2	--	1	29.1	16.6	2					
Viburnum rafinesquianum	32.4	--	1								
Plantation total shrub layer	2256.5a	258.1	38	1857.5a	393.5	12	370.1b	52.4	3	4.0553	.023

1/Based on Student-Newman-Keuls test of those means indicated as significantly different by ANOVA.

Table 8.--F-ratio and probability values for significant (p=<0.10) shrub layer LEAF, TWIG, and WOOD biomass 3-way ANOVA tests for treatment combinations applied to conifer plantations near Isabella, Minnesota

Species/ANOVA tests	Model			Main effects			Independent Variable 1			Independent Variable 2			Independent Variable 3			Interaction		
	Leaf	Twig	Wood	Leaf	Twig	Wood	Leaf	Twig	Wood	Leaf	Twig	Wood	Leaf	Twig	Wood	Leaf	Twig	Wood
Alnus crispa																		
YEAR-PREP-RELEASE	3.741	3.620	3.832	4.633	4.284	4.817	9.013	8.142	9.402							2.625	2.788	2.600
	.007	.008	.006	.004	.006	.003	.001	.001	.001							.051	.041	.053
YEAR-PREP-SPECIES	2.360		2.529	3.124	2.483	3.349	4.837	3.809	5.194									
	.042		.031	.016	.044	.012	.004	.012	.003									
YEAR-SPECIES-RELEASE	4.035	3.804	4.100	5.489	4.938	5.666	9.717	8.638	10.061							2.582	2.671	2.534
	.004	.006	.004	.002	.003	.002	.001	.001	.001							.050	.045	.054
Amelanchier spp.																		
YEAR-SPECIES-RELEASE	1.940	1.897	2.136	2.108	2.064	2.336				2.820		2.640						1.955
	.068	.075	.045	.072	.078	.049				.082		.095						.090
Betula papyrifera																		
YEAR-PREP-SPECIES	6.406		4.390	5.881		4.116	5.446	3.204	3.328				5.952		6.040	7.806		5.121
	.011		.030	.015		.039	.023	.080	.074				.045		.044	.012		.035
YEAR-SPECIES-RELEASE								3.975			4.138							
								.078			.096							
Corylus cornuta																		
YEAR-PREP-RELEASE																		
Populus tremuloides																		
YEAR-PREP-RELEASE		2.119	2.162	2.332	2.760	2.778	2.796	3.521	3.472									
		.078	.073	.069	.038	.038	.059	.029	.030									
YEAR-SPECIES-RELEASE				2.330	2.848	2.856	3.765	5.027	4.961									
				.091	.050	.050	.031	.012	.013									
Rosa acicularis																		
YEAR-PREP-RELEASE								2.136	2.205									
								.093	.084									
YEAR-SPECIES-RELEASE							2.225	2.375	2.424									
							.082	.067	.062									
Rubus strigosus																		
YEAR-PREP-RELEASE	4.601	4.304	4.760	5.750	5.955	5.819	3.244	3.646	3.312				4.312	3.101	4.500	3.547	2.790	3.790
	.001	.001	.001	.001	.001	.001	.020	.012	.018				.013	.043	.011	.003	.013	.002
YEAR-SPECIES-RELEASE	3.567	3.591	3.552	5.408	5.990	5.305	6.324	7.701	6.195				2.719		2.783	2.151		2.204
	.001	.001	.001	.001	.001	.001	.001	.001	.001				.064		.060	.045		.040
Plantation total																		
YEAR-PREP-RELEASE										2.556		2.309						
										.075		.097						

Interaction Independent Variables 1-2			Interaction Independent Variables 1-3			Interaction Independent Variables 2-3		
Leaf	Twig	Wood	Leaf	Twig	Wood	Leaf	Twig	Wood
			3.808	3.490	3.938			
			.033	.042	.030			
			3.570	3.759	3.480			
			.021	.017	.023			
			2.388	2.326	2.626	3.775	3.730	3.874
			.058	.063	.041	.040	.041	.037
9.712		3.845	10.504		10.006			
.010		.075	.014		.016			
			2.419	2.393	2.406			
			.054	.056	.055			
11.863	10.593	12.532	2.921		3.214	4.050	3.252	4.463
.001	.001	.001	.025		.016	.011	.027	.007
			2.742	2.207	2.815			
			.020	.054	.018			
			2.153					
			.077					

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