The Effect of Forage Seeding On Vegetation Dynamics And the Early Growth and Survival of Lodgepole Pine (*Pinus contorta* var. *latifolia* Engelm.) on a Forest Clear-cut.

by

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Abstract

Field trials of orchardgrass (*Dactylis glomerata* L.), smooth bromegrass (*Bromus inermis* Leys.), alsike clover (*Trifolium hybridum* L.), and a mixture by weight of 40% orchardgrass, 40% alsike clover, and 20% white clover (*Trifolium repens* L.), with five seeding rates by weight (0.5, 1.5, 3.0, 6.0 and 12.0 kg/ha), were conducted on a forest clear-cut in the Very Dry, Cool Montane Spruce biogeoclimatic subzone in the southern interior of British Columbia. The treatments were monitored for the first two growing seasons for their influence on the vegetation dynamics, and the resultant interactions of the vegetation on the growth and survival of planted 1+0 lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) seedlings.

Forage seeding had no effect on lodgepole pine survival. There was no significant difference in the height, basal diameter or stem volume growth of lodgepole pine in 1990 among different species of forage or between domestic forages and native vegetation. In the second year of the study (1991), decreases in the increment in lodgepole pine basal diameter were weakly associated with increasing seeding rate; however, lodgepole pine height, and stem volume remained unaffected by species or seeding rate of forages. There was no difference in the effect of different forage species or native vegetation on lodgepole pine growth in 1991. Stem volumes were lower in 1990 and 1991 on

conifers with surrounding vegetation compared to the control groups with competing vegetation removed. Unit needle mass decreased with the absence of vegetation in 1991. There was a positive correlation between cover of orchardgrass and overwinter rodent damage of the lodgepole pine seedlings following the first growing season; however, lodgepole pine survival was independent of rodent damage.

Density, cover, and height of vegetation were positively correlated with pure live seeds sown per ha, although this effect was delayed to the second growing season for height, and cover.

Two-dimensional partitioning of the cover indicated that the seeded fraction of the total vegetative response was influenced by seeding rate and species of forage sown in both growing seasons. The variability introduced by native vegetation masked the treatment effect in the first year, such that overall there was no treatment effect for total vegetative cover.

Initial germination of forages was not linearly related to the initial cover of soil, litter or wood on the plots; however, development of the vegetation, in particular the clovers, was often correlated with the initial cover of these non-floristic cover components.

Table of Contents

List of Tables

List of Figures

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1. Introduction

Competition has been identified as a major interaction between conifers and herbaceous plants (McLean and Clark 1980, Nordstrom 1984). Little research, however, has been done in British Columbia to quantify the competition between conifer seedlings and seeded forages or to identify any positive interactions between them. Moreover, there remains inadequate information quantifying the effects of forage species, seeding rates and forage mixes on the competitive balance between conifer and forages.

Species and rate of seeding of forages will also affect the botanical mix of native vegetation and the forage production on a clear-cut site. Despite the important influence of seeded vegetation on both range management and silviculture, vegetation dynamics following forage seeding have never been monitored quantitatively on a clear-cut in British Columbia (Nordstrom 1984).

This research follows recommendations in the report prepared by Pitt (1989) for the Ministry of Forests outlining a five-year plan for integrated forest/range research in British Columbia. The research was conducted in cooperation with the Forest Resource Development Agreement (FRDA) Project 3.55 research, "The Effects of Cattle Grazing, Forage Seeding, Basal Scarring and Leader Damage on Forest Regeneration," and was aimed at complementing the information generated in that program (Newman *et al.* 1989).

1.1. Objectives and Hypotheses

The objectives of this research are as follows:

(1) to determine the effects of three forage species and an operational range forage mix, and five seeding rates on the growth and survival of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) on a forest clear-cut in the Very Dry, Cool Montane Spruce (MSxk) biogeoclimatic subzone; and,

(2) to determine the effects of five seeding rates on the establishment, growth and dynamics of three domestic forages and an operational range forage mix on a forest clear-cut in the MSxk biogeoclimatic subzone.

1.1.1. Research Hypotheses

These objectives are embodied in the research hypotheses of the experiment, namely:

(1) Forage species affects lodgepole pine growth and survival. Competitive advantage among forages will not be equally expressed; forages with greater cover, height, and production potential will impact lodgepole pine seedlings more than forages with limited growth potential;

(2) Seeding rate of forage affects lodgepole pine growth and survival. Increased seeding rate by mass and pure live seeds sown results in

increasing cover and density of forages. A negative response in the lodgepole pine (mortality, decreased rate of growth) will correspond to increasing cover and density of the forages;

(3) Seeding rate affects establishment, growth and dynamics of vegetation on forest clear-cuts. The relationship between seeding rate and subsequent production, height, density, and cover of forages remain unquantified on forest clear-cuts in British Columbia. For example, a high seeding rate may result in a stand consisting of many small plants and a low seeding rate may result in a stand of a few large plants, yet both rates could have the same dry matter production and canopy cover; and,

(4) Vegetation dynamics on forest clear-cuts affects the growth and survival of lodgepole pine. Competitive balance between lodgepole pine and herbaceous vegetation will be affected by the varying herbaceous vegetation cover, density, dry matter production, and height resulting from different seeding rates, and species present.

1.1.2. Statistical Hypotheses

The following null hypotheses, derived from the research hypotheses, were tested in this research:

(1) Species of domestic forage has no effect on the height, basal diameter, unit needle mass, damage and survival of lodgepole pine seedlings;

(2) Seeding rate of domestic forage has no effect on the height, basal diameter, unit needle mass, damage and survival of lodgepole pine seedlings;

(3) Seeding rate has no effect on the cover, height, density, and dry matter production of domestic forages on forest clear-cuts; and

(4) Cover, height, density and dry matter production of vegetation have no effect on the height, basal diameter, unit needle mass, damage and survival of lodgepole pine seedlings.

1.2. Treatments and Levels

Two factors, species at four levels, and seeding rate at five levels (Table 1) were arranged in a completely random design in all factorial combinations. Two controls were included in the randomization: a single control for both species and seeding rate, consisting of lodgepole pines with no seeded vegetation, in addition to a control for tree growth consisting of lodgepole pines with competing herbaceous vegetation removed.

Forage species were selected from the forages that

have been suggested as suitable for the MSxk (Nordstrom 1984), and each represents a different class of forage. Species included a legume (alsike clover, *Trifolium hybridum* L.), a bunch grass (orchardgrass, *Dactylis glomerata* L.), a sod grass (smooth bromegrass, *Bromus inermis* Leys.), and an operational forage mixture (Table 1). Seeding rates were selected to provide a broad comparison, higher and lower than the current operational rate of approximately 3 kg/ha.

Table 1. Seeding rates of orchardgrass (*Dactylis glomerata* L.), smooth bromegrass (*Bromus inermis* Leys.), alsike clover (*Trifolium hybridum* L.), and a mixture by weight of 40% orchardgrass, 40% alsike clover, and 20% white clover (*Trifolium repens* L.) at Tunkwa Lake in 1990.

Species	Rate	
	(kg/ha)	(live seed/m^2)
Orchardgrass	0.5	35
	1.5	104
	3.0	208
	6.0	416
	12.0	833
Smooth bromegrass	0.5	11
	1.5	32
	3.0	65
	6.0	130
	12.0	260
Alsike clover	0.5	26
	1.5	79
	3.0	157
	6.0	314
	12.0	628
Mixture	0.5	38
	1.5	126
	3.0	230
	6.0	461
	12.0	921

1.3. Literature Review

1.3.1. Conifer - Vegetation Interactions

Clark and Mclean (1975), in a laboratory study, concluded that survival, height, and plant mass of six-month old lodgepole pine seedlings decreased as density of orchardgrass increased. Lodgepole pine survival increased by four times ($P<0.05$), height increased by over one-fifth ($P<0.05$), and the average dry weight of lodgepole pine shoots plus roots increased ten times ($P<0.05$) between the highest grass density (9.0 kg/ha) and no grass competition. Moreover, greater competition to lodgepole pine occurred with orchardgrass, a non-rhizomatous plant, than with pinegrass (*Calamagrostis rubesens* Buckl.), which is weakly rhizomatous. The response of lodgepole pine to grass competition was independent of a 2-, 4-, or 10-day watering interval.

Clark and McLean (1979) conducted seeding rate and forage species field trials in the southern interior of British Columbia on a subalpine, lodgepole pine site burned and cleared of native vegetation. The seeding rate trial consisted of orchardgrass sown at four rates from 2.2 - 17.9 kg/ha, and the forage species trial included orchardgrass, timothy (*Phleum pratense* L.), smooth bromegrass, red fescue (*Festuca rubra* L.), hard fescue (*Festuca ovina* var. *duriscula* (L) Koch), and crested wheatgrass (*Agropyron cristatum* (L) Gaertn.) with their seeding rates adjusted to

account for variable seed number per unit mass of the different species. Tree survival, grown from seed in the field, was not affected ($P>0.05$) by density of orchardgrass sowing after four years. Total biomass of pine seedlings was reduced by 68 to 93% ($P<0.05$) by presence of forages, and average stem height was reduced by 59 to 71% ($P<0.05$) at forage seeding rates greater than 4.5 kg/ha. Individual forage species did not differ ($P>0.05$) in their influence on the survival or growth of lodgepole pine.

Trowbridge and Holl (1992) reported that seeding alsike clover at rates of 10, 20, and 30 kg/ha had no effect ($P<0.05$) on the survival or height growth of planted lodgepole pine seedlings in the first three years. In the fourth year lodgepole pine height was reduced marginally ($P<0.05$) in clover plots compared to control plots with native vegetation. Lodgepole pine diameter growth decreased ($P<0.05$) with seeding rate during the first three growing seasons; however, differences in the diameter increment were not significant ($P>0.05$) in the fourth year after planting.

Baron (1962) concluded that the survival, after one year, of planted ponderosa pine (*Pinus ponderosa* Dougl.) in northern California was impeded by orchardgrass seeding compared to a control consisting of native vegetation with no seeded grass.

Krueger (1983) found no difference ($P>0.05$) in the survival or height growth of ponderosa pine, Douglas-fir

(*Pseudotsuga menziesii* (Mirbel) Franco.), western larch (*Larix occidentalis* Nutt.), and western white pine (*Pinus monticola* Dougl.) seedlings in areas seeded to a mixture of orchardgrass, timothy, tall oatgrass (*Arrhenatherum elatius* (L.) Presl.), smooth bromegrass, and white clover (*Trifolium repens* L.) at 2.68 kg/ha, as compared to unseeded areas in eastern Oregon.

Klinger (1986) reported that the growth and survival of two-year old Douglas-fir seedlings was decreased ($P<0.05$) by the presence of four different seeding mixtures (Table 2) in north eastern Oregon; however, only the mixture containing red fescue, a strong-sod forming grass, resulted in survival below the minimum requirement for tree stocking.

Table 2. Seeding mixtures and rates used by Klinger (1986).

Mixtures	Rate (kg/ha)
Colonial bentgrass (*Agrostis tenuis* Sibth.)	2.2
Orchardgrass (*Dactylis glomerata* L.)	5.6
Big trefoil (*Lotus pendunculatus* Cav.)	3.4
Total	11.2
Intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.)	33.6
Orchardgrass	5.6
Big trefoil	3.4
Total	42.6
Red fescue (*Festuca rubra* L.)	11.2
Orchardgrass	5.6
Big trefoil	3.4
Total	20.2
Pubescent wheatgrass (*Agropyron trichophorum* (Link) Richt.)	33.6
Orchardgrass	5.6
Big trefoil	3.4
Total	42.6

Squire (1977) found that the presence of *Poa australis* decreased ($P<0.01$) the increment in mean height by 32%, and decreased ($P<0.05$) the increment in basal area 5 cm above the ground by 51% of Monterey pine (*Pinus radiata* D. Don) in the first two years after planting in south-western Australia.

Elliot and White (1987), in a field study in a logged and burnt-over area in Arizona, concluded that orchardgrass decreased ($P<0.05$) ponderosa pine seedling height by 24% compared to unvegetated treatments, but was not different than the influence of native vegetation. Orchardgrass also decreased ($P<0.05$) tree diameters by 21% compared to no vegetation, and by 15% compared to native vegetation. Orchardgrass had no influence ($P>0.05$) on tree survival, but did reduce ($P<0.05$) the pre-dawn xylem moisture potential in the conifers.

Eissenstat (1980), and Eissenstat and Mitchell (1983), conducted a study in which container-grown Douglas-fir was grown with a 5:3:2 mixture by weight of orchardgrass, timothy, and red clover (*Trifolium pratense* L.) at 28 kg/ha. The seeding rate was chosen to maximize potential interactions between the species. Pre-dawn and midday xylem moisture potentials in Douglas-fir were decreased ($P<0.05$) by the presence of the forage in the first year, but not the following year, and Douglas-fir survival was not affected ($P>0.05$) in either year.

1.3.2. Vegetation Dynamics

Vegetation dynamics following forage seeding onto clear-cuts has never been monitored quantitatively in any ecotype in British Columbia (Nordstrom 1984). Literature concerning vegetation dynamics in the Montane Spruce and similar ecosystems is typically a collection of anecdotal and operational information listing forage species or mixes that have been deemed appropriate for use through 'trial and error' (Christ 1934, Pickford and Jackman 1944, Pringle and McLean 1962, Eddleman and McLean 1969, McLean and Bawtree 1971, Berglund 1976, Carr 1980). Other studies have included vegetation dynamics as supplemental information to other research, and are often qualitative.

Anderson and Elliot (1957) visually estimated the ground cover of several forage species following seeding onto burnt over land in the Peace River region. One year following seeding, smooth bromegrass varied between 33 and 78% ground cover, and alsike clover varied between 2 and 48%. All sites and plots were noted to be highly variable.

Brooke and Holl (1988) reported broadcast seeding on snow-covered clear-cuts in the southern interior of British Columbia resulted in successful establishment of orchardgrass, timothy and smooth bromegrass; however, it was up to 23 times less successful ($P>0.05$) in the establishment of alsike and white clover. A survey of existing winter seeding establishment (percent of pure live seed sown

resulting in established plants) showed the following results: orchardgrass, 2.3%; timothy, 1.2%; smooth bromegrass, 1.3%; and clovers, 0.1%. Moreover, two years after seeding, orchardgrass had 21.9% establishment from winter seeding and 12% from spring seeding, compared to alsike clover, which had 0.2% and 13.2% establishment respectively, for these two timings of seeding. Winter seeded orchardgrass retained 50% of its germinated population between the first and second year, whereas, spring-seeded orchardgrass retained 30% of its first year population.

Clark and McLean (1979) reported a mixture of timothy, orchardgrass, smooth bromegrass, crested wheatgrass, and alsike clover increased ($P<0.05$) forage production over a four-year period following seeding by 40 to 200%, compared to native vegetation. Differences in forage production resulting from the seeding rates of 2.2 to 17.9 kg/ha diminished over time; the production from the high rate declined ($P<0.05$) by 33% between the second and the fourth year, and production from the low rate increased ($P<0.05$) by 29% during this period.

Klock, Tiedemann and Lopushinsky (1975) defined successful forage establishment on disturbed mountain slopes of north-central Washington State as "greater than 20% vegetative cover within two years of seeding." Given this criteria, they found orchardgrass and smooth bromegrass were

among the successful species if sown at rates of 6.7 to 10.1 kg/ha.

1.3.3. Other Influences of Forage Seeding

Beyond the immediate influence of forage seeding on botanical composition and conifers, forage seeding also influences other aspects of the ecosystem.

Quinton (1984) found that the largest portion of cattle diets on a forest clear-cut in south-central British Columbia seeded to forage was composed of graminoids including seeded grasses; however, the highest utilization relative to availability was of forbs which included alsike clover seeded onto the site.

Sullivan and Sullivan (1984) found that seeding domestic forages strongly positively influences rodent populations of deer mice (*Peromyscus maniculatus* Wagner) and voles (*Microtus spp.*) on clear-cuts of the Interior Douglas-Fir biogeoclimatic zone.

The preceding literature review reveals the lack of definitive information on the influence of forage seeding on the synecology of early seral forest sites. The often conflicting results of previous experimentation and the lack of information relevant to British Columbia's ecotypes exemplifies the need for more quantitative experimentation, and this research was aimed at addressing this lack of information.

2. Study Site

The study site for this research is located near Tunkwa Lake (120^0 57′ W., 50^0 30′ N.) in the southern interior of British Columbia (Figure 1). It was classified within Phase IIa, Engelmann spruce (lodgepole pine)/ grouseberry - pinegrass, on sandy morainal gentle slopes, in the Very Dry, Cool Montane Spruce (MSxk) biogeoclimatic subzone (Hope *et al.* 1991). The elevation of the site is 1450 m, with a slope of 3% and a north-west aspect. Soil at the site is a melanic brunisol. The site supported a climax stand of lodgepole pine and Engelmann spruce before logging (Newman, pers. comm., 1990).

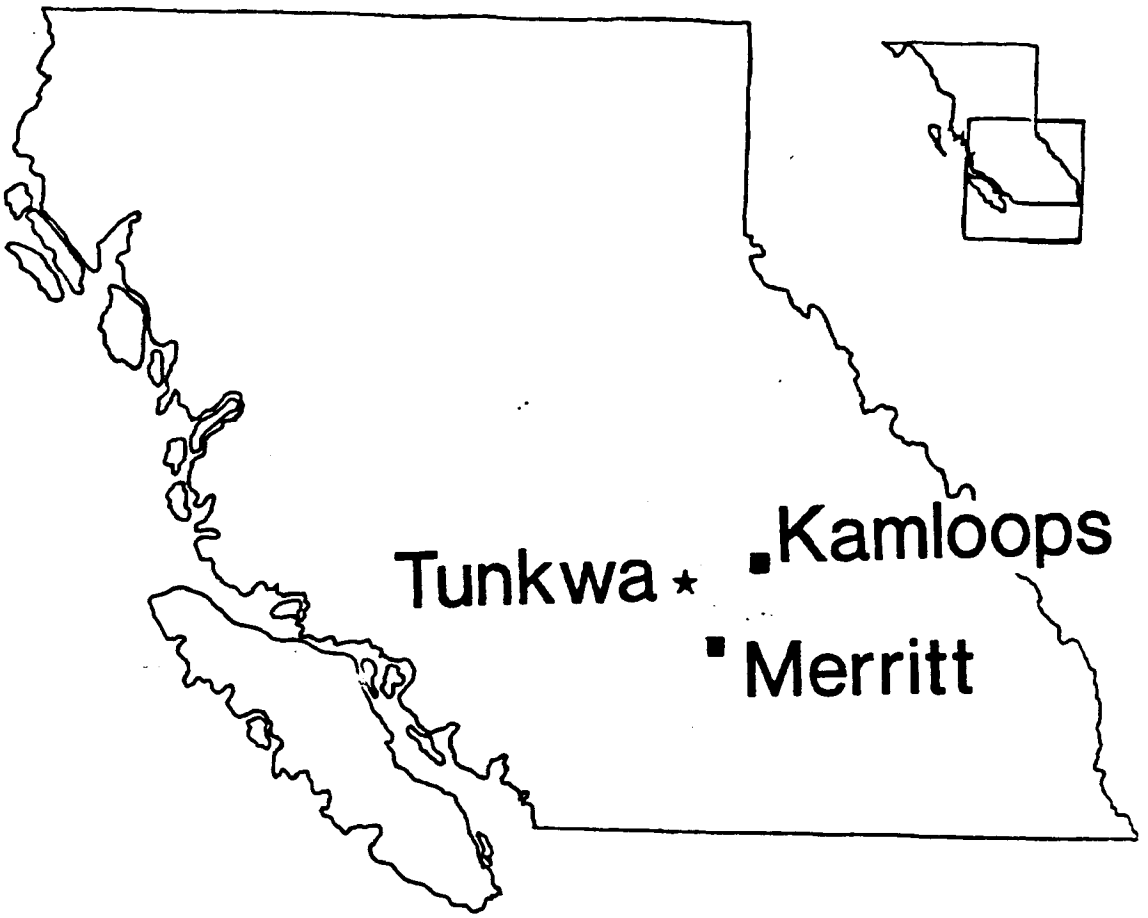


Fig. 1. Location of Tunkwa Lake research site.

3. Methods

3.1. Experimental Set-up

3.1.1. Site Preparation

The research site and surrounding area was clear-cut logged in the winter of 1988/89, and logging debris and waste were bunched and burned in the fall of 1989 as part of operational forest management in the area. All other site preparations were conducted in the spring of 1990 between the time of snow-melt and bud-break on the lodgepole pine seedlings.

The experimental site was enclosed with a 4-m high paige wire fence to exclude livestock and wild ungulates. The site contained 88, 4X4-m plots which were located with permanent markers placed in the ground. To ensure a continuous 2.5-m spacing of the trees from plot to plot, 1-m buffer strips were laid out between the plots. A minimum 4-m buffer (planted to trees) was located around the perimeter of the plots to eliminate edge effects.

To achieve a desired average mineral soil exposure of 15-25%, and to mix mineral soil with any unburned forest litter, plots were scarified by hand with garden rakes; each plot was passed over once completely to ensure even soil disturbance.

3.1.2. Forage Seeding

Alsike clover and white clover were coated with a clay-*Rhizobium leguminosarum* var. *trifolii* mixture which provided an average 2000 live *Rhizobium* cells per seed. This coating also added to the weight of seeds, decreasing the number of pure live clover seeds per unit mass.

Forages were seeded onto the plots by hand immediately following snow-melt. Seed required for each 0.0016-ha plot was calculated and this allotment was divided into quarters; each quarter of the plot was seeded by evenly scattering the seeds in a smooth sweeping motion from the centre of the plot. This method allowed for equal distribution of seed in the plots. Seeding after snow-melt ensured there was adequate moisture for germination.

3.1.3. Lodgepole Pine Planting

Lodgepole pine seedlings (1+0 PSB 313) were planted immediately after forage seeding. Each plot contained four lodgepole pine seedlings at a 2.5-m spacing, and each tree was tagged with a number for sampling records.

3.2. Germination Trials

Germination trials of the forage seed were conducted in accordance with the procedure outlined by the Association of Official Seed Analysts (1978), and were used to calculate the number of pure live seed sown/ha (Table 1).

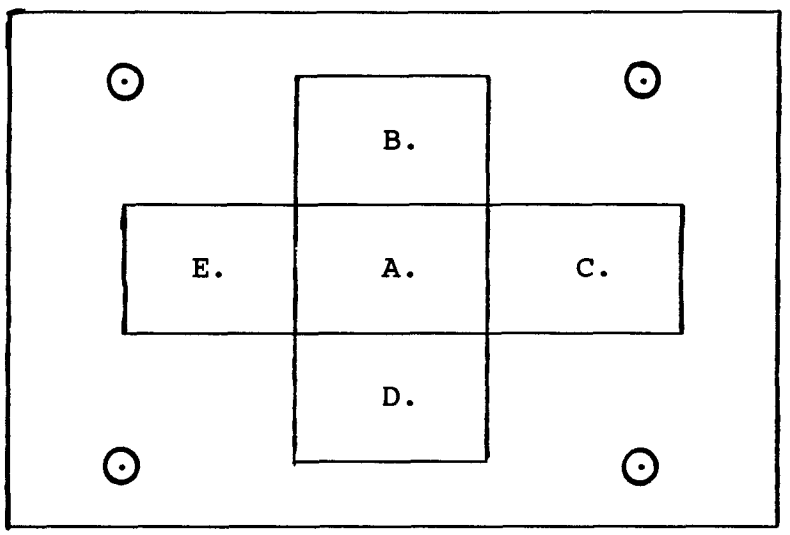
3.3. Vegetation Dynamics Measurements

Two sets of vegetation dynamics measurements were conducted within each plot: one centred on a randomly selected lodgepole pine seedling to assess interaction of lodgepole pine and forages, and the second in the middle of the plot, without the influence of the tree seedlings, to assess the dynamics of the herbaceous vegetation. Sample locations within each 4x4-m plot were allocated as indicated in Figure 2. Sampling for forage production occurred in 1x1-m sub-plots; each sub-plot, and the quarter section of the sub-plot actually clipped, were selected randomly; however, the same sub-plot was not clipped twice during the study.

This sampling strategy allowed adequate interspersion of clippings while avoiding the confounding effects of the edge of the 4X4-m plots. This sampling strategy also ensured that clippings did not influence the results of the dynamics measurements in the centre of the plot, nor the competitive balance between lodgepole pine and other vegetation.

3.3.1. Cover

Before lodgepole pine planting and forage seeding in 1990 the cover of litter, wood and exposed mineral soil in each plot was estimated with the canopy coverage method in 20- X 50-cm frames (Daubenmire 1959). This method was also used to determine the cover of all vegetation, litter, wood and exposed mineral soil twice each year, coincident with the conifer measurements.



North-east corner

⊙ Conifer Seedlings

A. Stand Dynamics Measurements
B-E. Forage Production Measurements

Fig. 2. Sampling locations within 4X4-m plots at Tunkwa Lake.

3.3.2. Density

In 1990, density was determined by counting the number of genets (Silvertown 1987:3) within a 20- x 50-cm frame at two intervals. The first was a density count of the seedlings established after lodgepole pine bud-break, but before the estimated time of significant drying in the upper 2.5-cm of soil. This is approximately representative of the maximum amount of field germination when moisture was adequate and before any substantial seedling death due to desiccation or competition occurred. The second density counts were conducted after lodgepole pine bud-set. In 1991 density counts were conducted twice, coincident with the lodgepole pine measurements.

3.3.3. Height

Height of all species included in the density counts was measured, to the nearest 0.1 cm, from ground level to the tip of the highest leaf extended upward on a plant ocularly estimated to be of average height within the plot.

3.3.4. Production

An estimate of the available forage production for herbivore consumption was determined from oven-dry samples obtained by clipping a 0.25-m^2 frame (50x50 cm) to a 5-cm stubble height. In both 1990 and 1991, forage production was determined at lodgepole pine bud set; vegetation was separated into one of the following six groups: smooth bromegrass, pinegrass, orchardgrass, clovers, other grasses,

and forbs. Each component was calculated separately in addition to the total for the plot. Shrubs were not included in forage production calculations as they were not considered a forage source.

3.4. Lodgepole Pine Measurements

Lodgepole pine survival, height, basal diameter, unit needle mass and damage were measured annually before the start of the lodgepole pine growing season (between snow-melt and bud-break) and immediately after the trees had set bud.

3.4.1. Survival and Damage

During each sampling period lodgepole pine survival and damage were assessed. Death was defined as 99% or greater necrotic needles. Damage classified as human, rodent, erosion, snow-press, lodging, frost, and other was also noted at this time, as was the type (scar, break or removal), size (% girdle and length) and location of the damage on the lodgepole pine.

3.4.2. Height

Height was measured to the nearest 0.1 cm on every tree from the soil surface to the tip of the terminal bud.

3.4.3. Basal Diameter

Basal diameter was measured to the nearest 0.1 mm with calipers placed around the stem immediately above the soil surface.

3.4.4. Unit Needle Mass

Unit needle mass (mass/conifer needle) was determined from an oven-dry sample of ten lodgepole pine needles, removed from the most recent growth along the main stem of all lodgepole pine seedlings in 1991 only. Needles collected in 1990 were too variable in their number collected per tree to produce meaningful results.

3.5. Weather Record

A daily record of maximum and minimum temperature, precipitation, maximum and minimum soil temperature, and soil moisture was collected, from an existing CR-21 Micro Data Logger on an adjacent FRDA project 3.55 research block, during the growing season of both study years.

3.6. Photographic Record

All treatments were photographed annually with a 35-mm SLR, with a 35-mm lens, at the last sampling date, to provide a visual reference during data analysis and presentation. Plots were photographed from the same position each year, 5 m perpendicular to the north-east corner, with a reference rod placed in the middle of the plot to aid in comparison.

3.7. Statistical Analysis

3.7.1. Vegetation Dynamics

The influence of seeding rate on vegetation height, density, total vegetative cover, and production was analyzed with an analysis of variance (ANOVA) for a completely random design with a factorial arrangement. The analysis has been adjusted (Table 3) for the unbalanced design that results from a single control being used for both main effect factors (Bergerud 1989). The analysis was carried out in three stages. The first stage was a two-way ANOVA conducted on a sub-set of the data without the control included; this analysis derived the sum of squares for both treatment factors and their interaction term. The second stage was a simple one-way ANOVA conducted on a new factor called "treatment"; this factor has 21 levels consisting of 20 levels of species and rate in all their possible factorial combinations, and another level for the control. The second stage derived the sum of squares for error and "treatment." The sum of squares for control was calculated by subtracting the sum of squares for species, rate and their interaction from the sum of squares for "treatment." The third stage of the analysis was to produce a composite ANOVA table and to calculate the mean squares and F-ratios in the normal manner.

Table 3. Analysis of variance for the influence of forage species and seeding rate by mass on vegetation production, vegetation density, vegetation height, and total vegetative cover.

Stage 1

Source of variation	Degrees of freedom	Sum of squares
Species	3	SSA
Rate	4	SSB
Species X Rate	12	SSAB
Error	60	Not Used

Stage 2

Source	df	SS
Treatment	20	SSM
Error	63	SSE

Stage 3

Source	df		SS
Species	(A-1)	3	SSA
Rate	(B-1)	4	SSB
Species X Rate	(A-1)(B-1)	12	SSAB
Control		1	SSC[1]
Error	[(A X B)+1](R-1)	63	SSE
Total	[{(A)(B)+1}{R}]-1	83	

[1]SSC = SSM - SSA - SSB - SSAB

Specific differences among species treatment means were determined using a set of individual degree of freedom contrasts (Table 4); a set of orthogonal contrasts was used to determine first (linear), second (quadratic extension) or third (cubic extension) order polynomial relationships due to seeding rate by mass (Table 5). Significant second and third order polynomials are not reported because they did not produce biologically meaningful results.

Table 4. Individual degree of freedom contrasts used to determine specific differences among species levels in the analysis of variance.

u1 = Mixture
u2 = Alsike Clover
u3 = Smooth Bromegrass
u4 = Orchardgrass

Contrast 1 (C1) = u1 vs. u2, u3, u4
Contrast 2 (C2) = u2 vs. u3, u4
Contrast 3 (C3) = u3 vs. u4

Tests of Orthogonality

	C1	C2	C3	
u1	-3	0	0	
u2	1	-2	0	
u3	1	1	-1	
u4	1	1	1	
Sum	0	0	0	= Linearly Independent

C1 vs C2 = 0 - 2 + 1 + 1 = 0
C1 vs C3 = 0 + 0 - 1 + 1 = 0
C2 vs C3 = 0 + 0 - 1 + 1 = 0 = Mutually Orthogonal

Table 5. Orthogonal contrast coefficients used to estimate polynomial models for seeding rate levels in the analysis of variance.

Seeding Rate kg/ha	Linear	Quadratic	Cubic	Deviation
0.5	-41	191	276	206
1.5	-31	47	-169	-460
3.0	-16	-119	-351	322
6.0	14	-270	293	-73
12.0	74	151	-49	5

3.7.2. Two-Dimensional Partitioning

The influence of seeding rate on botanical composition, as reflected in the changes in cover, was analyzed with two-dimensional partitioning. Two-dimensional partitioning is a statistical procedure suitable for simultaneously determining the relative contribution of various components to the response of an additive multivariate system. It also determines the effect treatments have on these individual components and the system as a whole (Eaton *et al.* 1986). As the name implies, the analysis consists of two stages, described as follows: in one dimension, total variation in cover is partitioned into orthogonalized cover components by linear regression analysis; in the second dimension, variation of each of the cover components, as expressed the coefficient of determination between total cover and a given cover component, is partitioned among treatment effects and error following the procedure outlined for the ANOVA of the vegetation dynamics data. These two dimensions become the columns and rows, respectively of the tables in which the

results are summarized. Sums of products are also calculated, which are the sum of the interactions between treatments and component pairs. The order in which the cover components are placed into the regression analysis in the first dimension is determined by their presumed developmental sequence; if components are deemed to have similar development, then they can be ordered by some other logical attribute.

To simplify the mathematics in the analysis, cover components with very small, or infrequent cover values, were grouped into one of following eight categories: litter and wood, bare mineral soil, orchardgrass, clovers, smooth bromegrass, native graminoids, native forbs, and native shrubs. A complete list of the species included in each of these cover categories is presented in Appendix 1. The ninth category, total cover, is the sum of the cover values for the eight previously listed categories.

These cover components were ordered into the analysis as they are listed above. Plant litter, wood and bare mineral soil were known to precede the vegetative cover components in the development of the site and, as the first in succession, were the first components entered into the regression analysis. The six vegetative cover components do not have a true developmental sequence, in that, none is a necessary precursor to the development of others. Differences in the speed of establishment of the various

plant categories were considered in the ordering, and the domestic species sown were the first to germinate on the site and, therefore, domestic species were entered into the analysis before the native vegetation.

The influence of forage seeding on total vegetative cover and its components, were also of interest, primarily because it was assumed that total non-floristic cover components have no influence on the competition among lodgepole pine and the surrounding vegetation. For this reason two-dimensional partitioning was also conducted on a sub-set of the cover data, utilizing only the vegetative cover components. For this second analysis, total vegetative cover was calculated as the sum of the six vegetative cover categories.

3.7.3. Lodgepole Pine

The effect of forage species and seeding rate by mass on lodgepole pine height, basal diameter, unit needle mass, damage and survival were analyzed using analysis of variance for a completely random design. The analysis has been modified similar to that used for vegetation dynamics with the two following exceptions (Table 6): a second error term was calculated for the sub-sampling of four lodgepole pines within each of the plots, and the entire three stage analysis was conducted twice. The second analysis was identical to the first except that the control for native vegetation was substituted with a control consisting of

Table 6. Analysis of variance for the influence of forage species and seeding rate by mass on lodgepole pine height, basal diameter, unit needle mass, damage and survival.

Stage 1

Source of variation	Degrees of freedom	Sum of squares
Species	3	SSA
Rate	4	SSB
Species X Rate	12	SSAB
Experimental Error	60	Not Used
Sampling Error	240	Not Used

Stage 2

Source	df	SS
Treatment	20	SSM
Experimental Error	63	SSE
Sampling Error	252	SSES

Stage 3

Source	df		SS
Species	(A-1)	3	SSA
Rate	(B-1)	4	SSB
Species X Rate	(A-1)(B-1)	12	SSAB
Controls		2	SSC[1]
Experimental Error	[(A X B)+1](S-1)	63	SSE
Sampling Error	r[{(A)(B)+1}{S-1}]	252	SSES
Total	[{(A)(B)+1}{R}{S}]-1	335	

[1]SSC = SSM - SSA - SSB - SSAB

lodgepole pine with no competing vegetation. The analysis must be conducted twice because the sum of squares for each individual control cannot be calculated from the pooled variance if both were analyzed simultaneously.

Individual degree of freedom contrasts for the species levels, and orthogonal contrasts for the seeding rate levels were identical to those used for the vegetation dynamics ANOVA (Tables 4 and 5).

The relationship between lodgepole pine basal diameter, height, unit needle mass, damage and survival to the number of pure live forage seeds sown, total vegetative cover, vegetation height, density, and production were analyzed with forward stepwise multiple regression and correlation. A separate regression was conducted for each forage species treatment for lodgepole pine basal diameter, height, unit needle mass, damage, and survival.

A chi-square analysis of 2 x 2 contingency tables for rodent damage and survival were used to determine if lodgepole pine survival was independent of rodent damage, and to determine if rodent damage and survival were homogenously distributed among species factors and controls.

4. Results

4.1. Germination Trials

Table 7 displays the results of the laboratory germination trials on forage species sown. These results were used to calculate the number of pure live seed sown per unit area (Table 1).

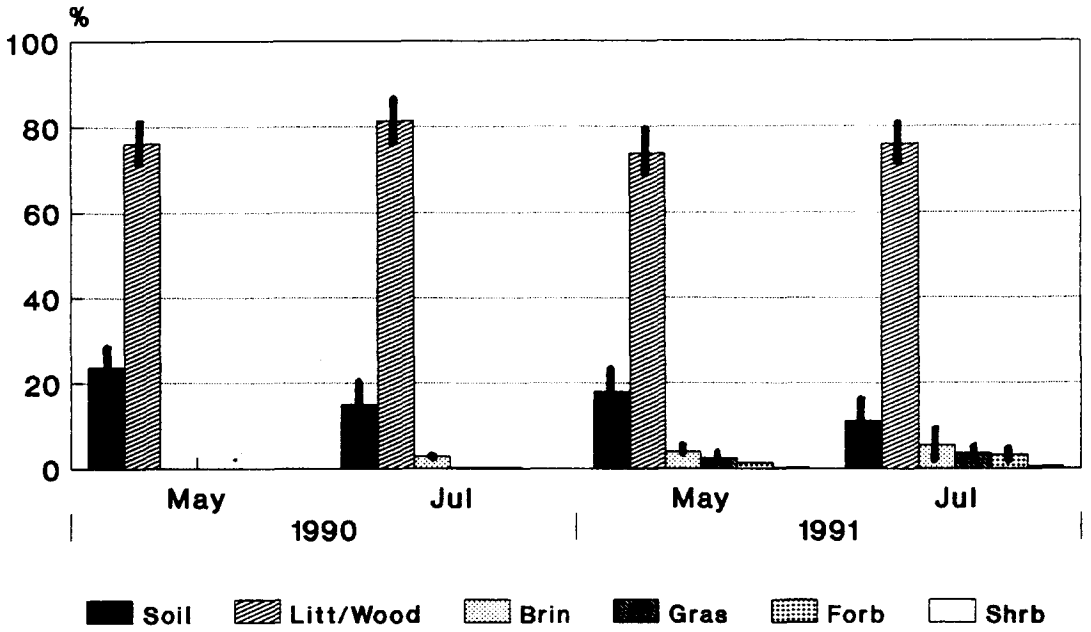
Table 7. Germination and purity of forage species sown at Tunkwa Lake in 1990.

Forage Species	Germination %	Pure live seed % of total weight
Orchardgrass	93	97
Smooth bromegrass	93	98
Alsike clover	89	100
White clover	90	99

4.2. Vegetation Dynamics

4.2.1. Cover

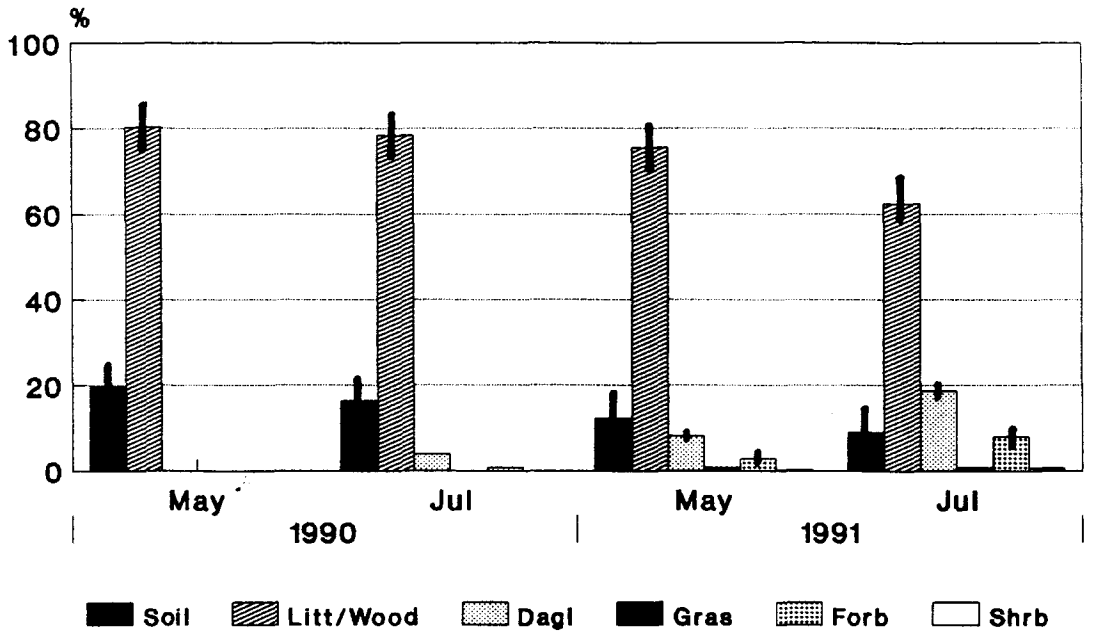
Before the planting of lodgepole pine and seeding of forages in 1990 the average cover on the site consisted of 24.7% bare mineral soil, 62.5% litter, and 9.2% wood. Figures 3 to 7 show the changes in cover categories for each forage species sown over the first two growing seasons.



Error bars = +/- one standard error.

BRIN	Smooth bromegrass.
FORB	Native forbs (Appendix 1).
GRAS	Native graminoids (Appendix 1).
LITT/WOOD	Plant litter and wood.
SHRB	Native shrubs (Appendix 1).
SOIL	Bare mineral soil.

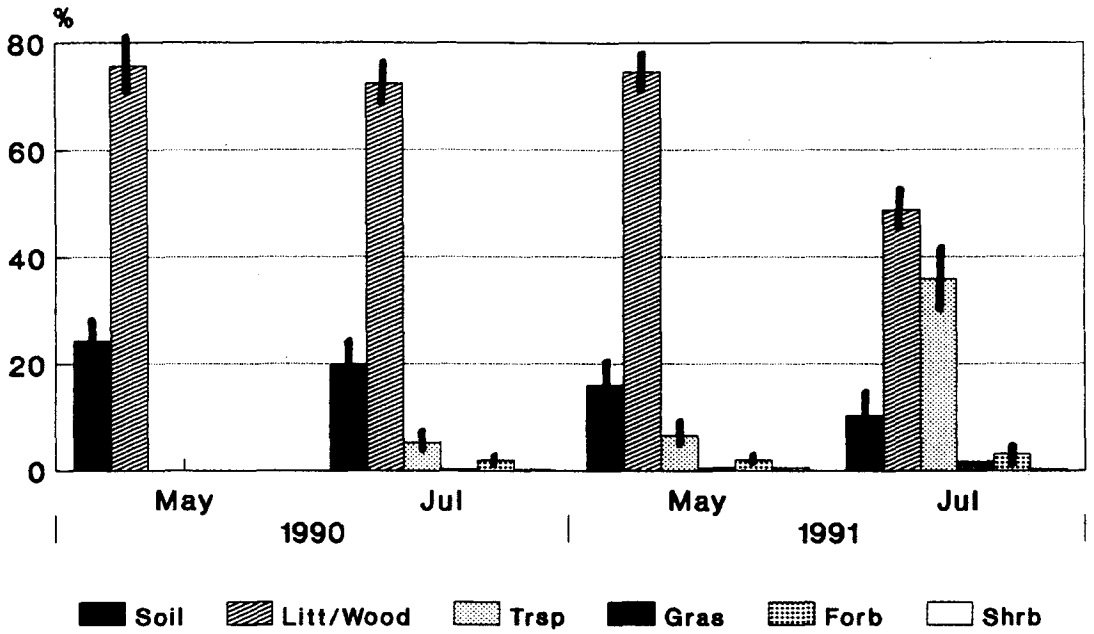
Fig. 3. Cover on plots sown to smooth bromegrass at Tunkwa Lake, May 1990 to July 1991.



Error bars = +/- one standard error.

DAGL	Orchardgrass.
FORB	Native forbs (Appendix 1).
GRAS	Native graminoids (Appendix 1).
LITT/WOOD	Plant litter and wood.
SHRB	Native shrubs (Appendix 1).
SOIL	Bare mineral soil.

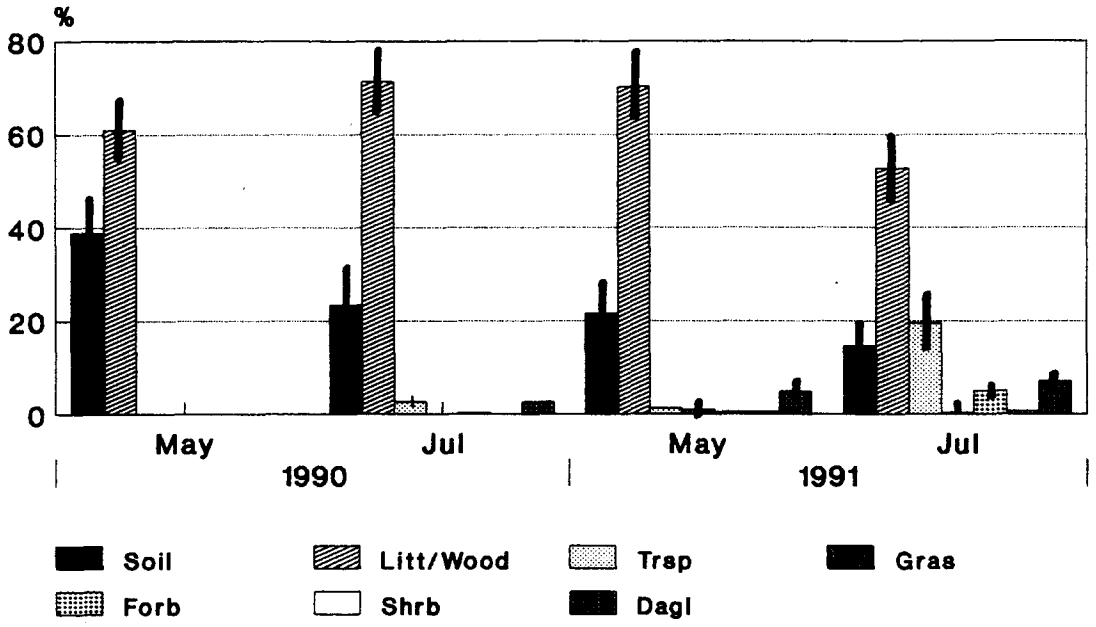
Fig. 4. Cover on plots sown to orchardgrass at Tunkwa Lake, May 1990 to July 1991.



Error bars = +/- one standard error.

FORB	Native forbs (Appendix 1).
GRAS	Native graminoids (Appendix 1).
LITT/WOOD	Plant litter and wood.
SHRB	Native shrubs (Appendix 1).
SOIL	Bare mineral soil.
TRSP	Clovers.

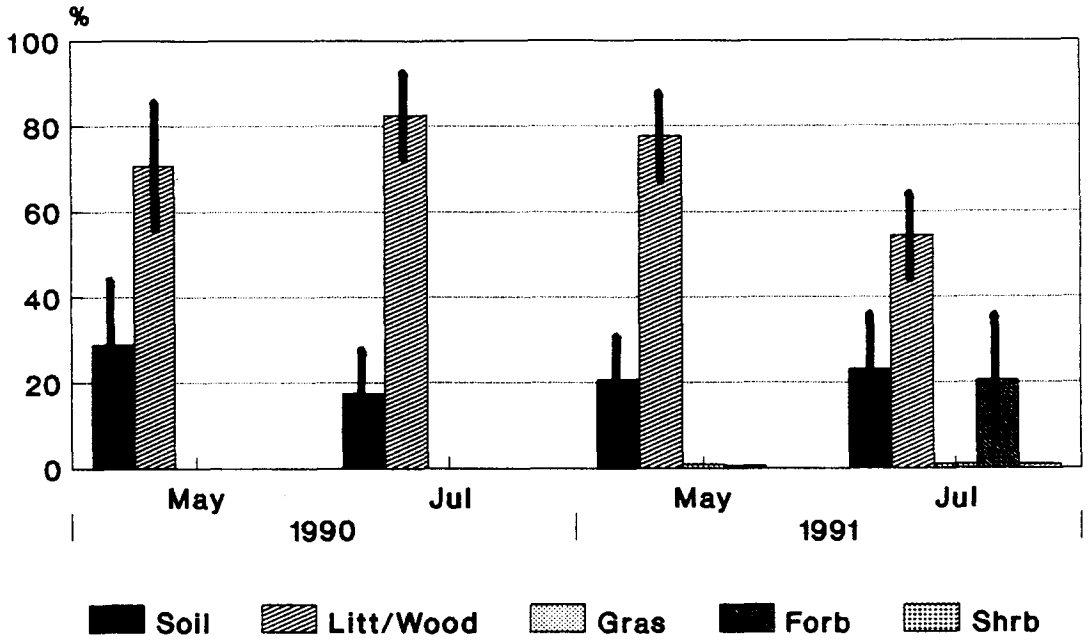
Fig. 5. Cover on plots sown to alsike clover at Tunkwa Lake, May 1990 to July 1991.



Error bars = +/- one standard error.

DAGL	Orchardgrass.
FORB	Native forbs (Appendix 1).
GRAS	Native graminoids (Appendix 1).
LITT/WOOD	Plant litter and wood.
SHRB	Native shrubs (Appendix 1).
SOIL	Bare mineral soil.
TRSP	Clovers.

Fig. 6. Cover on plots sown to the mixture at Tunkwa Lake, May 1990 to July 1991.



Error bars = +/- one standard error.

FORB	Native forbs (Appendix 1).
GRAS	Native graminoids (Appendix 1).
LITT/WOOD	Plant litter and wood.
SHRB	Native shrubs (Appendix 1).
SOIL	Bare mineral soil.

Fig. 7. Cover on plots with native vegetation at Tunkwa Lake, May 1990 to July 1991.

Total vegetative cover in 1990 averaged 4.4%, and was not influenced ($P>0.05$) by species or seeding rate (Table 8). Total vegetative cover in 1991 averaged 26.8%, and increased linearly with seeding rate by mass in 1991 ($r^2=0.16$, $P<0.05$). On plots seeded to the mixture, 18.3% of the variability in total vegetative cover was accounted for ($P<0.06$) by a positive linear relationship between cover and pure live seeding rate. On plots seeded to alsike clover, total vegetative cover increased linearly with the initial cover of wood on those plots in both 1990 ($r^2=0.255$, $P<0.02$), and 1991 ($r^2=0.182$, $P<0.06$). Total vegetative cover on plots seeded to alsike clover averaged 30.9% in 1991, and was greater ($P<0.025$) than the average of those seeded to orchardgrass or smooth bromegrass (20.2%).

Table 8. Vegetative cover (%) at Tunkwa Lake in 1990 and 1991.

Species	Year		Rate kg/ha				
			0.5	1.5	3.0	6.0	12.0
Orchardgrass	1990	avg	2.3	1.5	7.5	6.8	4.5
		SE	0.8	1.0	3.0	3.3	1.7
	1991	avg	24.3	5.3	41.5	32.0	40.0
		SE	21.1	1.7	17.7	14.9	18.4
Smooth brome	1990	avg	0.8	2.3	6.0	3.4	2.3
		SE	0.9	1.7	3.5	0.9	0.9
	1991	avg	18.8	6.8	7.5	14.3	11.3
		SE	17.1	4.6	5.4	5.9	5.5
Alsike clover	1990	avg	3.0	11.8	2.3	3.4	12.5
		SE	1.4	10.2	0.8	0.9	9.8
	1991	avg	9.0	55.8	43.0	37.0	49.5
		SE	4.0	22.6	13.8	15.6	29.2
Mixture	1990	avg	2.3	6.0	1.5	7.5	4.5
		SE	1.6	4.7	1.7	4.4	1.0
	1991	avg	3.0	34.0	17.8	43.0	49.5
		SE	3.5	19.0	11.3	26.2	20.1
Native Vegetation	1990	avg	0.0				
		SE	0.0				
	1991	avg	21.0				
		SE	16.5				

In 1990, litter and wood (36%), and bare mineral soil (47%) contributed the greatest amount of variability in the total cover of the plots, although neither of these two cover variables were influenced ($P>0.05$) by treatment (Table 9). The combined contribution to total variability of all three seeded vegetation cover classes was 8%, this similar to the variability contributed by the three native vegetative cover components (9%), which was almost exclusively due to the contribution of native forbs.

When the non-floristic cover components were eliminated from the two-dimensional analysis (Table 10), the greatest amount of variability in the total vegetative cover was derived from the clovers (39%) and the native forbs (41%). Total vegetative cover and the native vegetative components did not respond linearly to seeding rate or species factors in 1990; however, the cover of clovers displayed a linear relationship ($r^2=0.16$, $P<0.025$) to seeding rate by mass. In addition, all three seeded cover components showed highly significant response to the species factor; however, a significant response in the seeded fraction was confounded by the contrasts used. They compared species sown exclusively to certain treatments, to other seeded species, which were not sown in these treatments.

Table 9. Two-dimensional partitioning of total sum of squares, expressed as a percentage of total cover at Tunkwa Lake in 1990[1].

Source	df	LW	SL	DG	TS	BI	GS	FB	SB	SP	TOT
Total	83	36	47	1	6	1	0	9	0	0	100
Treatment	20	10	6	0	2	0	0	2	0	0	23
Rate	4	3	1	0	0	0	0	0	0	1	7
Linear	1	2	0	0	0	0	0	0	0	-1	1
Quad	1	1	0	0	0	0	0	0	0	1	2
Cubic	1	0	1	0	0	0	0	0	0	2	3
Dev	1	0	0	0	0	0	0	0	0	-1	0
Species	3	1	0	0***[2]	1**	0***	0	0	0	0	3
C1	1	0	0	0	0	0	0	0	0	-1	0
C2	1	0	0	0	1***	0*	0	0	0	-1	0
C3	1	0	0	0***	0	0***	0	0	0	2	3
S X R	12	6	5	0	0	0	0	2	0	1	14
Control	1	0	0	0	1***	0	0	0	0	-1	0
Error	63	26	41	1	4	1	0	7	0	-2	77

[1] Zero values can result from rounding values less than 0.500 down to 0.

[2] *, **, ***, Significant at 0.05, 0.01, and 0.001 levels, respectively.

Explanation of Abbreviations:

LW	Litter and wood.
SL	Bare mineral soil.
DG	Orchardgrass.
TS	Clovers.
BI	Smooth bromegrass.
GS	Native graminoids (Appendix 1).
FB	Native forbs (Appendix 1).
SB	Native shrubs (Appendix 1).
SP	Sums of products.
TOT	Total cover.
df	Degrees of freedom in each column.
S X R	Species by rate interaction term.

Linear, quad, cubic and dev refer to the orthogonal contrasts used to find polynomial relationships for seeding rate.

C1, C2, and C3 refer to the individual degree of freedom contrasts for species factors.

Table 10. Two-dimensional partitioning of total sum of squares, expressed as a percentage of total vegetative cover at Tunkwa Lake in 1990[1].

Source	df	DG	TS	BI	GS	FB	SB	SP	TOT
Total	83	12	39	6	1	41	1	0	100
Treatment	20	5	14	3	0	10	0	-9	25
Rate	4	0	3	0	0	2	0	2	4
Linear	1	0	3*[2]	0	0	0	0	-2	2
Quad	1	0	0	0	0	0	0	2	1
Cubic	1	0	0	0	0	0	0	3	0
Dev	1	0	0	0	0	1	0	-1	1
Species	3	3***	5*	2***	0	1	0	-8	4
C1	1	0	0	0	0	0	0	-1	0
C2	1	1*	5**	0**	0	1	0	-7	3
C3	1	2***	0	1***	0	0	0	-0	1
S X R	12	2	6	1	0	7	0	-3	15
Control	1	0	0	0	0	0	0	0	2
Error	63	7	25	3	1	30	1	9	75

[1] Zero values can result from rounding values less than 0.500 down to 0.

[2] *, **, ***, Significant at 0.05, 0.01, and 0.001 levels, respectively.

Explanation of Abbreviations:

DG Orchardgrass.
TS Clovers.
BI Smooth bromegrass.
GS Native graminoids (Appendix 1).
FB Native herbs (Appendix 1).
SB Native shrubs (Appendix 1).
SP Sums of products.
TOT Total vegetative cover.
df Degrees of freedom for each column.
S X R Species by rate interaction term.

Linear, quad, cubic and dev refer to the orthogonal contrasts used to find polynomial relationships for seeding rate.

C1, C2, and C3 refer to the individual degree of freedom contrasts for species factors.

In 1991, alsike clover and native forbs contributed the greatest amount of variability to total cover (Table 11). Litter and wood contributed 6% of the total variability in cover and their value declined (r^2=0.12, P<0.0005) with increasing seeding rate. The cover of litter and wood on plots sown to alsike clover in 1991 (59.1%), were less (P<0.025) than on those sown to orchardgrass (71.7%) or smooth bromegrass (87.1%). Native graminoids had 1.6% cover in 1991 on plots sown to forages; this was greater (P<0.05) than the cover of graminoids on plots with native vegetation alone (0.9%).

When the non-floristic cover components are removed from the two-dimensional analysis in 1991 (Table 12), orchardgrass and the clovers contributed 81% of the variability in total vegetative cover. As detailed earlier, total vegetative cover was greater on plots sown to alsike clover than the average response of the seeded graminoids. None of native cover components were influenced by seeding rate or species of forage sown (P>0.05). Orchardgrass responded to treatment in the same manner as it did in 1990, and the clovers exhibited a positive linear association with seeding rate by mass again (r^2=0.16, P<0.01). The effect of treatments on smooth bromegrass could not be determined in 1991 because smooth bromegrass contributed a negligible amount of variability to total vegetative cover.

Table 11. Two-dimensional partitioning of total sum of squares, expressed as a percentage of total cover at Tunkwa Lake in 1991[1].

Source	df	LW	SL	DG	TS	BI	GS	FB	SB	SP	TOT
Total	83	6	0	12	31	0	8	41	2	0	100
Treatment	20	3	0	6	12	0	2	9	0	-10	23
Rate	4	1**[2]	0	0	2	0	0	3	0	-1	7
Linear	1	1***	0	0	0	0	0	0	0	-1	1
Quad	1	0	0	0	0	0	0	0	0	1	2
Cubic	1	0	0	0	0	0	0	3*	0	0	3
Dev	1	0	0	0	1	0	0	0	0	-2	0
Species	3	1*	0	4***	5**	0	0	0	0	-7	3
C1	1	0	0	0	1	0	0	0	0	-1	0
C2	1	0*	0	2***	4***	0	0	0	0	-6	0
C3	1	0	0	2***	0	0	0	0	0	-0	3
S X R	12	1	0	2	4	0	1	5	0	0	14
Control	1	0	0	0	1*	0	0*	1	0	-2	0
Error	63	3	0	6	18	0	6	32	2	10	77

[1] Zero values can result from rounding values less than 0.5000 down to 0.

[2] *, **, ***, Significant at 0.05, 0.01, and 0.001 levels respectively.

Explanation of Abbreviations:

LW	Litter and wood.
SL	Bare mineral soil.
DG	Orchardgrass.
TS	Clovers.
BI	Smooth bromegrass.
GS	Native graminoids (Appendix 1).
FB	Native herbs (Appendix 1).
SB	Native shrubs (Appendix 1).
SP	Sum of the products.
TOT	Total cover.
df	Degrees of freedom for each column.
S X R	Species by rate interaction term.

Linear, quad, cubic and deviation refer to the orthogonal contrasts to determine polynomial relationships for seeding rate.

C1, C2, and C3 refer to the individual degree of freedom contrasts for species factors.

Table 12. Two-dimensional partitioning of total sum of squares, expressed as a percentage of total vegetative cover at Tunkwa Lake in 1991[1].

Source	df	DG	TS	BI	GS	FB	SB	SP	TOT
Total	83	22	59	0	5	13	1	0	100
Treatment	20	11	32	0	1	4	0	-15	32
Rate	4	1	6*	0	0	1	0	4	7*
Linear	1	1	4**[2]	0	0	0	0	4	5*
Quad	1	0	0	0	0	0	0	0	1
Cubic	1	0	0	0	0	1	0	-0	1
Dev	1	0	1	0	0	0	0	-0	0
Species	3	6***	17***	0	0	0	0	5	11*
C1	1	0	1	0	0	0	0	0	0
C2	1	1**	16***	0	0	0	0	5	7*
C3	1	4***	0	0	0	0	0	-0	4
S X R	12	4	8	0	1	1	0	8	14
Control	1	0	1	0	0	1	0	-1	0
Error	63	11	27	0	4	9	1	43	68

[1] Zero values can result from rounding values less than 0.500 down to 0.

[2] *, **, ***, Significant at 0.05, 0.01, and 0.001 levels, respectively.

Explanation of Abbreviations:

DG Orchardgrass.
TS Clovers.
BI Smooth bromegrass.
GS Native graminoids (Appendix 1).
FB Native herbs (Appendix 1).
SB Native shrubs (Appendix 1).
SP Sum of the products.
TOT Total vegetative cover.
df Degrees of freedom for each column.
S X R Species by rate interaction term.

Linear, quad, cubic and deviation refer to the orthogonal contrasts used to determine polynomial relationships for seeding rate.

C1, C2, and C3 refer to the individual degree of freedom contrasts for species factors.

4.2.2. Density

Density of vegetation increased linearly (r^2=0.18, P<0.0005) with seeding rate by mass, and with pure live seeding rate (r^2=0.23, P<0.001) in 1990; however, there was no linear relationship (P>0.05) between these variables in 1991 (Table 13).

Density of vegetation on plots sown to smooth bromegrass in June 1990 increased linearly (r^2=0.60, P<0.001) with increasing pure live seeding rate; the strength of this relationship declined in late July 1990 (r^2=0.29, P<0.01), and remained at this level to July 1991 (r^2=0.32, P<0.01).

Density of vegetation on plots sown to orchardgrass also had a positive linear relationship (r^2=0.80, P<0.001) with pure live seeding rate in June 1990, and also declined in July 1990 (r^2=0.37, P<0.005); there was no linear relationship (P>0.05) between these two variables in July 1991. Variability in the density of vegetation on plots sown to orchardgrass in June 1990 was further explained (r^2=0.85, P<0.001) by correlating the average cover of litter in addition to pure live seeding rate (Figure 8).

Density of vegetation on plots sown to the mixture was linearly related (r^2=0.30, P<0.01) to pure live seeding rate in June 1990; however, there was no linear relationship between density and pure live seeding rate on these plots in any other sampling period.

Table 13. Average density of vegetation in 1990 and 1991 at Tunkwa Lake.

Seeding rate			Density plant/m^2							
			Date (year-month)							
	kg/ha	seed/m^2	90-06		90-07		91-05		91-07	
			Avg	SE	Avg	SE	Avg	SE	Avg	SE
DAGL	0.5	35	5	0	23	2	18	1	30	1
	1.5	104	8	0	10	1	15	1	35	2
	3.0	208	35	2	83	3	38	2	285	12
	6.0	416	70	1	73	2	45	1	38	0
	12.0	833	158	3	130	6	58	2	63	2
BRIN	0.5	11	5	0	10	1	13	1	30	1
	1.5	32	5	0	8	1	8	1	15	1
	3.0	65	5	0	35	1	15	1	23	1
	6.0	130	8	0	15	1	30	2	58	4
	12.0	260	70	2	75	5	45	2	105	5
TRHY	0.5	26	13	1	8	0	5	1	40	2
	1.5	79	13	1	30	2	38	2	50	2
	3.0	157	103	6	50	3	30	2	40	1
	6.0	314	75	4	38	1	18	1	28	2
	12.0	628	620	43	158	13	70	5	100	6
MIX	0.5	38	8	1	118	1	8	1	10	1
	1.5	115	60	5	33	3	38	2	65	3
	3.0	230	10	1	5	1	18	1	78	6
	6.0	461	150	7	130	7	50	2	40	2
	12.0	921	298	12	50	2	28	1	28	1
NATV		0	0	0	0	0	5	0	133	12

DAGL Orchardgrass.
BRIN Smooth bromegrass.
TRHY Alsike clover.
MIX Mixture by weight of 40% orchardgrass, 40% alsike clover, and 20% white clover.
NATV Native vegetation control.

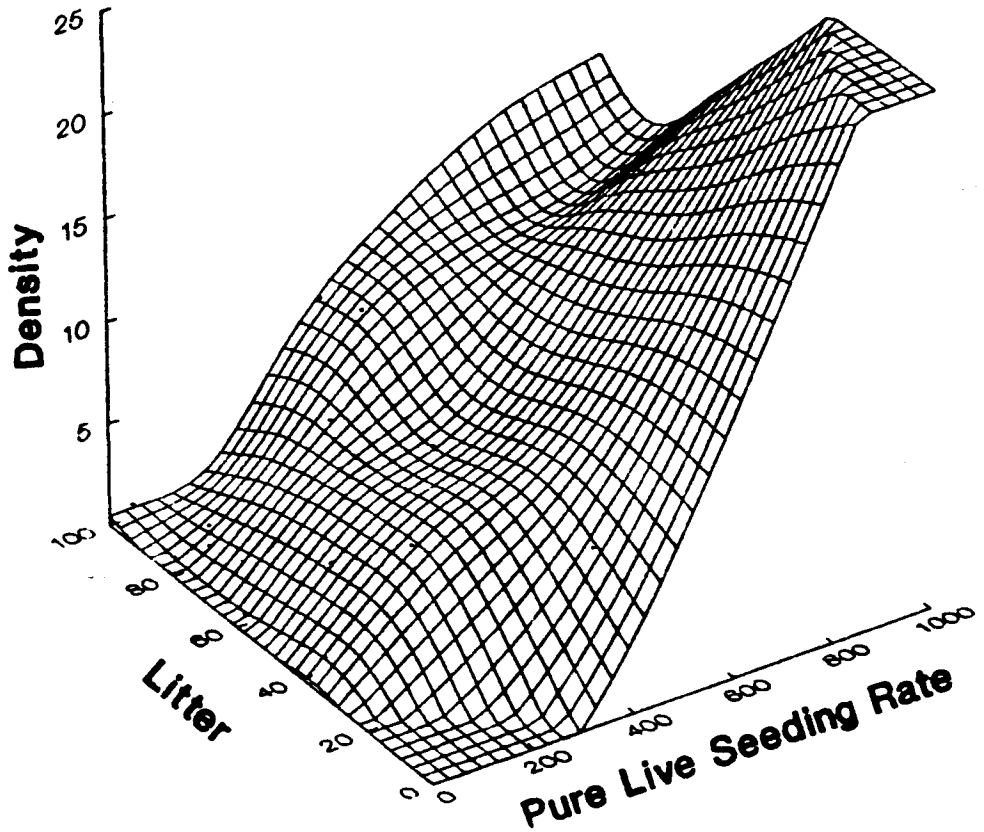


Fig. 8. The influence of pure live seeding rate (seed sown/m^2) of forages, and the initial cover (%) of litter on the density of seedlings (plants/m^2) in 1990 on plots sown to orchardgrass at Tunkwa Lake.

Density of vegetation on plots sown to alsike clover increased linearly (r^2=0.45, P<0.001) with increasing pure live seeding rate in June 1990. The strength of the linear relationship declined in July 1990 (r^2=0.21, P<0.04), and there was no linear relationship (P>0.05) between density on plots sown to alsike clover and pure live seeding rate in 1991. Additional variability in density of vegetation on plots sown to alsike clover in July 1990 was accounted for by the initial cover of wood on these plots (R^2=0.72, P<0.001) (Figure 9). Density of vegetation on plots sown to alsike clover was correlated (r^2=0.36, P<0.005) with the initial cover of wood in July 1991.

No pattern could be discerned from the incremental recruitment and mortality of plants, in either the seeded fraction, or total density, given the parameters measured in this study. Moreover, there was no relationship (P>0.05) between establishment of seeded species, as a percentage of pure live seed sown, and seeding rate or species of forage sown in any sampling period.

Density of vegetation was unaffected (P>0.05) by species of forage sown in 1990. In 1991, smooth bromegrass had an average density of 26 plants/m^2, and was 62% lower (P<0.025) than the average density of orchardgrass (90 plants/m^2).

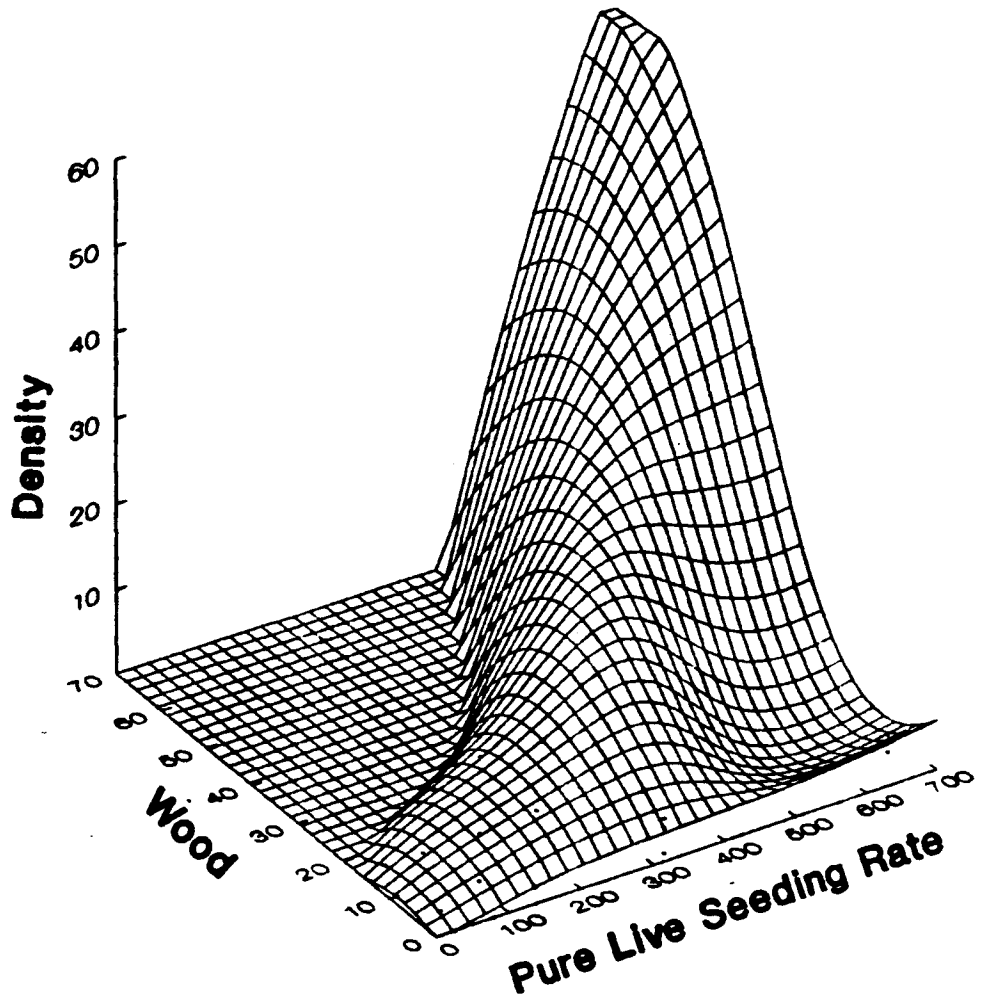


Fig. 9. The influence of pure live seeding rate (seed sown/m^2) and the initial cover (%) of wood on the density of vegetation (plants/m^2) in 1990 on plots sown to alsike clover at Tunkwa Lake.

The interaction ($P<0.0005$) among species and seeding rate did not produce any biologically meaningful results (Figure 10).

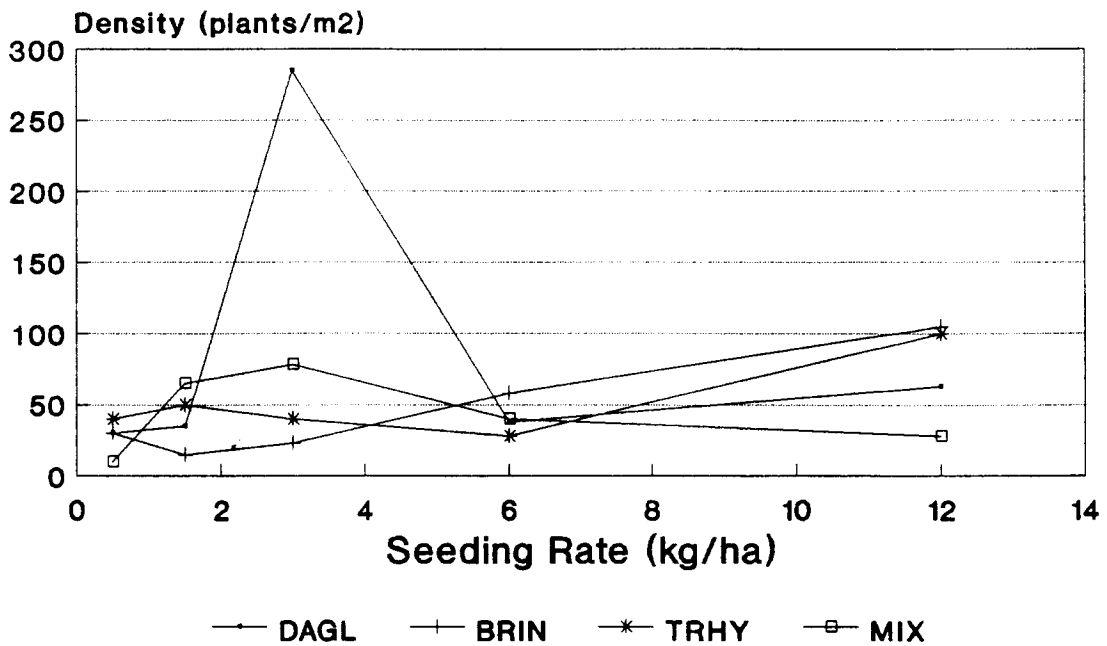


Fig. 10. The interaction of the mean response of forage species and seeding rate on the average density of vegetation (plants/m^2) in 1991 at Tunkwa Lake.

4.2.3. Height

The average height of herbaceous vegetation was 5.1 cm in 1990 and 20.4 cm in 1991. A small portion of the increase in plant height (r^2=0.09, P<0.01) can be attributed to increasing seeding rate by mass in 1991 (Table 14). The average height of vegetation on plots seeded to alsike clover in 1991, 21.9 cm, was 3% lower (P<0.005) than the average height of vegetation on plots seeded to orchardgrass and smooth bromegrass.

There was a positive linear relationship (r^2=0.206, P<0.04) in 1991 between average height and pure live seeding rate on plots sown to the mixture. In 1990, height of vegetation on plots sown to alsike clover was positively correlated (r^2=0.325, P<0.04), with the initial cover of mineral soil and wood, and in 1991, height of vegetation was positively correlated (r^2=0.37, P<0.004) with initial cover of wood on these plots.

Table 14. Average height of herbaceous vegetation (cm) in 1990 and 1991 at Tunkwa Lake.

Species			Rate (kg/ha)				
			0.5	1.5	3.0	6.0	12.0
Orchardgrass	1990	avg	2.3	2.0	10.3	13.3	7.3
		SE	2.2	1.4	2.3	4.0	2.2
	1991	avg	20.5	14.5	30.3	36.5	34.0
		SE	12.4	5.2	7.3	18.4	16.5
Smooth brome	1990	avg	3.8	1.5	5.8	9.0	4.0
		SE	4.3	1.1	1.7	1.8	1.7
	1991	avg	16.0	11.0	11.5	37.3	11.5
		SE	13.3	7.1	4.5	15.3	4.4
Alsike clover	1990	avg	1.5	2.0	2.5	1.8	2.5
		SE	1.0	1.0	1.4	0.9	1.4
	1991	avg	5.3	22.5	24.3	22.8	34.8
		SE	2.5	9.9	5.8	10.2	19.8
Mixture	1990	avg	0.8	8.5	6.3	5.3	3.3
		SE	0.9	5.3	7.2	2.2	1.4
	1991	avg	2.5	24.3	9.0	32.5	32.8
		SE	2.9	10.1	7.4	18.8	5.8
Native Vegetation	1990	avg	0.0				
		SE	0.0				
	1991	avg	11.5				
		SE	5.4				

4.2.4. Production

Production of herbaceous vegetation averaged 20.3 kg/ha in 1990, and in 1991, averaged 834.8 kg/ha; production was not linearly related ($P>0.05$) to seeding rate by mass in either year (Table 15). Average production of plots with seeded vegetation in 1991 was 10 times greater ($P<0.05$) than production of plots with native vegetation alone (79.3 kg/ha). Average forage production in 1990 on plots sown to orchardgrass (33.7 kg/ha) was greater ($P<0.05$) than on plots sown to smooth bromegrass (6.3 kg/ha). In 1991, average forage production on plots sown to alsike clover (1471.5 kg) was greater ($P<0.005$) than the average of the domestic grasses (521.0 kg/ha).

Forage production in 1990 increased linearly ($r^2=0.186$, $P<0.06$) with increasing pure live seeding rate on plots sown to smooth bromegrass. Forage production in 1990 was positively correlated ($R^2=0.651$, $P<0.001$) with the initial cover of litter and wood on plots sown to alsike clover. In 1991, forage production was positively correlated ($r^2=0.227$, $P<0.03$), with the initial cover of mineral soil on plots sown to the mixture, and positively correlated ($r^2=0.204$, $P<0.05$) with the initial cover of wood on plots sown to alsike clover.

Seeded vegetation comprised 86% of total production in 1990, and 83% of total production in 1991. The relative contribution of seeded vegetation to total yield did not differ ($P>0.05$) among species or seeding rate levels in either year.

Table 15. Average production of herbaceous vegetation (kg/ha) in 1990 and 1991 at Tunkwa Lake.

Species			Rate (kg/ha)				
			0.5	1.5	3.0	6.0	12.0
Orchardgrass	1990	avg	15.2	8.3	30.7	47.3	66.9
		SE	11.8	6.7	31.9	42.7	68.2
	1991	avg	161.9	910.4	495.4	1084.1	364.6
		SE	62.8	622.2	153.7	721.1	191.4
Smooth brome	1990	avg	6.9	0.8	0.9	3.4	19.5
		SE	8.0	0.5	0.6	1.3	14.8
	1991	avg	650.3	101.5	61.2	881.2	499.7
		SE	228.6	104.5	58.5	368.2	262.7
Alsike clover	1990	avg	0.5	18.0	6.5	7.7	35.9
		SE	0.6	12.3	2.6	5.8	33.0
	1991	avg	576.0	1429.7	1010.1	3069.8	1271.8
		SE	432.4	950.6	697.2	1223.7	988.5
Mixture	1990	avg	16.4	19.6	94.1	24.3	3.8
		SE	10.8	22.0	39.9	17.1	2.5
	1991	avg	108.4	1149.1	1121.6	925.4	1578.4
		SE	120.9	1284.8	499.7	788.9	1322.3
Native Vegetation	1990	avg	0.0				
		SE	0.0				
	1991	avg	79.3				
		SE	69.9				

4.3. Lodgepole Pine

4.3.1. Growing Season

Individual lodgepole pines commenced candling (initiation of terminal bud growth) in 1990 between June 6 and June 19. Terminal buds on the lodgepole pine set (end of terminal bud growth) between July 20 and July 25. Lodgepole pine commenced candling in 1991 between May 30 and June 14, and terminal buds set on the lodgepole pine in the 1991 growing season between July 22 and July 29.

4.3.2. Survival and Damage

There was 100% survival of lodgepole pine during the 1990 growing season. There was 2.8% mortality during the overwinter period between the 1990 and 1991 growing seasons, and an additional 3.1% during the 1991 lodgepole pine growing season; cumulative mortality during the two years of the study was 5.9% of the lodgepole pine planted in May 1990.

A single lodgepole pine seedling was damaged (human induced) during the first growing season. Rodents damaged 23.9% of the lodgepole pine during the overwinter period between the 1990 and 1991 growing season; rodents were the only source of damage during this period. Rodent damage was almost exclusively scars of 2 cm or less in length resulting from chewing the bark and cambium. The remainder of rodent-induced damage was removal of the main lodgepole pine stem or laterals. There was no damage recorded during the 1991

lodgepole pine growing season. Lodgepole pine survival was independent ($P>0.05$) of rodent damage, and rodent damage was equally distributed among the forage species factors and controls. Rodent damage was correlated ($r^2=0.534$, $P<0.001$) to increases in total vegetative cover on plots sown to orchardgrass.

4.3.3. Height

The average lodgepole pine height at the end of the growing season in 1990 was 19.1 cm, and 21.3 cm in 1991. Height growth in 1990 averaged 6.5 cm, and there was no difference ($P>0.05$) among species or seeding rate factors, nor between seeded vegetation and native vegetation ($P>0.05$). The height growth in 1990 of lodgepole pine grown with vegetation (6.4 cm) was 14% less ($P<0.05$) than the control group grown without competing vegetation (7.3 cm). An interaction ($P<0.05$) between seeding rate and species factors did not produce any biologically meaningful results (Figure 11). The average height growth in 1991 was 3.9 cm, and was not affected by forage species sown or seeding rate (Table 16).

Lodgepole pine height growth in 1990 was negatively correlated with forage production ($r^2=0.291$, $P<0.01$) on plots sown to orchardgrass. In 1991, lodgepole pine height growth was correlated ($R^2=0.341$, $P<0.03$) with total vegetative cover and density of vegetation on plots sown to alsike clover.

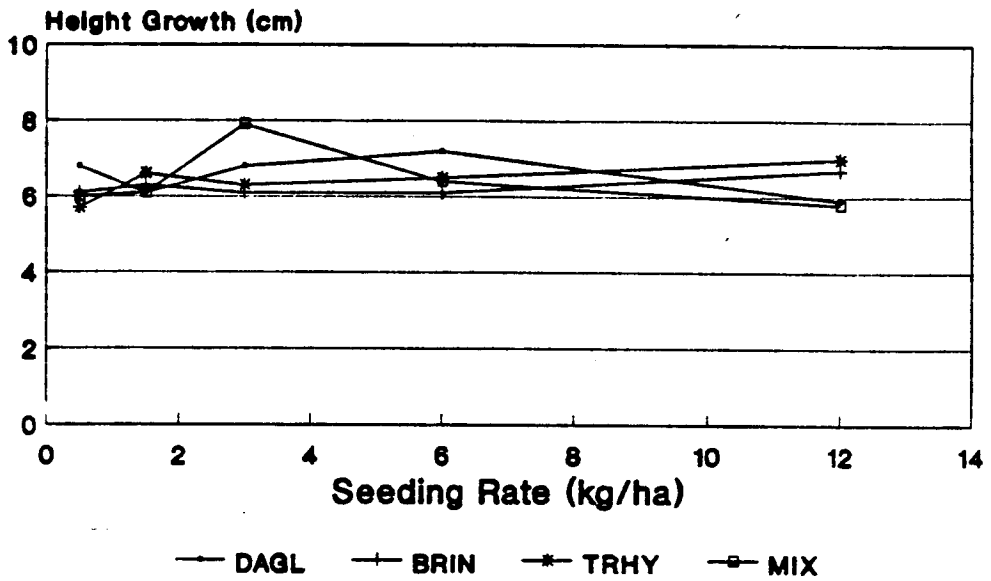


Fig. 11. The interaction of the mean response of forage species and seeding rate on lodgepole pine height growth (cm) in 1990 at Tunkwa Lake.

Table 16. Average lodgepole pine height growth (cm) in 1990 and 1991 at Tunkwa Lake.

Species	Year		Rate (kg/ha)				
			0.5	1.5	3.0	6.0	12.0
Orchardgrass	1990	avg	6.8	6.1	6.8	7.2	5.9
		SE	0.4	0.6	0.3	0.5	0.3
	1991	avg	3.2	4.8	4.0	4.4	3.6
		SE	0.7	0.8	0.8	1.0	0.9
Smooth brome	1990	avg	6.1	6.3	6.1	6.1	6.7
		SE	0.4	0.4	0.3	0.5	0.5
	1991	avg	2.9	5.1	4.1	4.9	2.6
		SE	0.8	0.8	0.8	1.0	0.5
Alsike clover	1990	avg	5.7	6.6	6.3	6.5	7.0
		SE	0.4	0.4	0.3	0.3	0.4
	1991	avg	2.7	5.1	4.3	2.8	3.4
		SE	0.8	1.1	0.8	0.5	0.8
Mixture	1990	avg	6.0	6.1	7.9	6.4	5.8
		SE	0.4	0.4	0.5	0.3	0.4
	1991	avg	2.9	3.4	4.4	2.5	4.2
		SE	0.6	0.7	0.9	1.1	0.9
Native Vegetation	1990	avg	6.4				
		SE	0.4				
	1991	avg	4.7				
		SE	0.5				
No Competing Vegetation	1990	avg	7.3				
		SE	0.4				
	1991	avg	4.8				
		SE	1.0				

4.3.4. Basal Diameter

The average lodgepole pine basal diameter at the end of the growing season in 1990 was 3.1 mm, and 5.5 mm in 1991. Basal diameter growth averaged 0.6 mm in 1990, and was not influenced by species or seeding rate. In 1991, basal diameter growth averaged 1.3 mm and was unaffected by species of forage sown (Table 17). Increment in basal diameter declined marginally (r^2=0.03, P<0.05) with increasing seeding rate by mass and also (r^2=0.07, P<0.07) with pure live seeding rate in 1991.

Increment in basal diameter in 1990 was negatively correlated (r^2=0.177, P<0.07) with forage production on plots sown to orchardgrass. In 1991, basal diameter growth was correlated (r^2=0.341, P<0.03) with total vegetative cover and density of vegetation on plots sown to alsike clover.

Table 17. Average lodgepole pine basal diameter growth (mm) in 1990 and 1991 at Tunkwa Lake.

Species	Year		Rate (kg/ha)				
			0.5	1.5	3.0	6.0	12.0
Orchardgrass	1990	avg	0.7	0.6	0.5	0.8	0.6
		SE	0.1	0.1	0.1	0.1	0.1
	1991	avg	1.3	1.4	1.1	1.3	1.2
		SE	0.2	0.5	0.3	0.3	0.2
Smooth brome	1990	avg	0.5	0.7	0.6	0.7	0.5
		SE	0.1	0.1	0.1	0.1	0.1
	1991	avg	1.0	2.1	1.4	2.1	0.8
		SE	0.2	0.3	0.3	0.3	0.1
Alsike clover	1990	avg	0.7	0.7	0.7	0.6	0.6
		SE	0.1	0.1	0.1	0.1	0.1
	1991	avg	1.0	1.4	1.5	0.9	0.6
		SE	0.3	0.3	0.3	0.2	0.2
Mixture	1990	avg	0.5	0.5	0.7	0.5	0.8
		SE	0.1	0.1	0.1	0.1	0.1
	1991	avg	1.4	0.9	1.1	1.5	0.8
		SE	0.2	0.1	0.3	0.4	0.2
Native Vegetation	1990	avg	0.4				
		SE	0.1				
	1991	avg	1.6				
		SE	0.2				
No Competing Vegetation	1990	avg	0.8				
		SE	0.1				
	1991	avg	1.5				
		SE	0.2				

4.3.5. Unit Needle Mass

The average mass of ten lodgepole pine needles taken from the current year's growth was 0.073 g at the end of the growing season in 1991. The ratio of unit needle mass at the end of the lodgepole pine growing season to the unit needle mass at the beginning of the growing season in 1991 averaged 1.076. There was no difference ($P>0.05$) in this growth ratio among species or seeding rate factors. The 1991 growth ratio of unit needle mass for the control with no competing vegetation averaged 0.667, and was lower ($P<0.025$) than the average ratio for lodgepole pine with surrounding vegetation.

4.3.6. Stem Volume

Stem volume on the conifer seedlings was estimated by the following formula: $(\text{Basal Diameter})^2(\text{Height})$.

Average growth in stem volume in 1990 was 1.1 $\pm$ 0.0 cm^3, and in 1991 averaged 4.4 $\pm$ 0.3 cm^3. Growth in stem volume did not differ among forage species or seeding rate, nor between seeded vegetation and the native vegetation control, in either year of the study. Average growth in stem volume in 1990 for conifers with surrounding vegetation (1.1 $\pm$ 0.0 cm^3) was 27% lower ($P<0.05$) than the control with competing vegetation removed (1.5 $\pm$ 0.1 cm^3). Average growth in stem volume in 1991 for conifers with surrounding vegetation (4.3 $\pm$ 0.3 cm^3) was 42% lower ($P<0.05$) than the control with competing vegetation removed (7.4 $\pm$ 1.5 cm^3).

4.4. Weather Record

The daily record for maximum and minimum temperature, precipitation, maximum and minimum soil temperature, and soil moisture during both growing seasons is detailed in Appendix 2.

During the 1990 lodgepole pine growing season there was 158.0 mm of precipitation and 336.7 growing degree days. In the 1991 lodgepole pine growing season there was 129.0 mm of precipitation, and 329.2 growing degree days.

The permanent wilting point in the upper 2.5 cm of soil, first occurred on July 21 in the 1990 lodgepole pine growing season, and on July 24 in the 1991 growing season. These dates marked the point at which pronounced seedling mortality due to desiccation could occur. The last spring frost occurred on June 5, 1990, just before the first lodgepole pine seedlings candled, and the first frost in the fall of 1990 occurred on September 30. Lodgepole pine bud-set during the first growing season, July 20-25, 1990, coincided with moisture levels below the permanent wilting point, 10-cm below the soil surface. The last spring frost of the second growing season occurred on June 19, and the first fall frost occurred on August 25. Permanent wilting point at the 10-cm soil level first occurred on August 14, 1991; lodgepole pine bud-set in the second growing season coincided with significant drying at the 10-cm soil level in the two previous weeks.

5. Discussion

5.1. Vegetation Dynamics

5.1.1. Early Influence of Seeding Rate

The number of pure live forage seeds sown had the greatest influence on vegetation dynamics of the parameters measured on this site. This is apparent in the relationship of plant density to seeding rate very early in the development of the vegetation. There were strong linear relationships between seeding rate and seedling density counts for most forage species in June 1990. As other factors influenced the dynamics beyond germination (microclimatic variability, interspecific and intraspecific competition) there was a decline in the strength of the relationship between seeding rate and density for all species sown.

Total vegetative cover in 1990 was not linearly related to seeding rate, because the seeded vegetation did not develop sufficiently in the first year for the differences in the plant numbers to express themselves as differences in total vegetative cover. The cover of domestic forage species was weakly influenced by seeding rate in 1990, but was masked by the variability introduced by the native species occurring on the plots. This is readily apparent in the two-dimensional partitioning of the cover data. During the second growing season, when the plants had established to a greater degree, a small portion (16.4%) of the

variability in vegetative cover was explained by the seeding rate. Once again a stronger treatment response was isolated in the seeded fraction, because uncontrolled variability was introduced with the native species on the plots.

Plant height also showed a patterned response to the seeding rate of forages in the second growing season. The weak relationship between seeding rate and plant height in the 1991 growing season could be a result of differences in the proportions of mature and immature herbaceous plants. Observation showed that herbaceous vegetation on plots seeded at higher rates tended to develop more rapidly than those at lower rates. It was more likely to have a higher proportion of immature, and, therefore, shorter vegetation, at the lower seeding rates than vegetation at the higher seeding rates. It is anticipated that as the stands develop, plant height will show no response to seeding rate, as most of the plants reach maturity, or plant height will be negatively related to seeding rate due to greater interspecific and intraspecific competition associated with higher seeding rates.

Plant production had no linear relationship with seeding rate in either growing season. The relationship of plant production to seeding rate was probably delayed similar to the response of total vegetative cover; the stand had not developed sufficiently to reflect differences in seeding rate. Alternately, other factors, such as

microclimatic variability, and distribution of available soil nutrients could mask the influence of seeding rate.

5.1.2. Differences in Plant Development

In most circumstances, seeded treatments produced vegetation with greater height, density, production, and total vegetative cover than the control plots with native vegetation alone. Although native and domestic forbs (clovers) both had a strong initial influence on vegetative cover, the seeded vegetation grew more rapidly than the native vegetation. This is evident in the contribution to variability in total vegetative cover by native forbs which declined by a third between the first and second growing seasons. Observation over the two growing seasons, however, showed that, except for lodgepole pine and the native shrubs, all of the species observed on the plots (Appendix 1) flowered by the fall of 1991. The exact influence of treatments on reproductive potentials of the various species, however, was not monitored.

Native herbaceous plants, although not as advanced in development as the seeded component of the vegetation, contributed 41% of the variability in total vegetative cover in 1990, and 13% of the variability in total vegetative cover in the second growing season. This is indicative of their importance in vegetation development, and also is a reflection of the uncontrolled distribution of native plants on the research site. The strong presence of the native

forbs in the botanical composition in the first year indicates that they are rapid in establishing following disturbance, although, once established they develop significantly slower than the domestic species. Plants which are included in the native forbs category (Appendix 1) are a mixture of weed or invader species, such as dandelion (*Taraxacum officinale* L.), and site-specific species, such as heart leaf arnica (*Arnica cordifolia* L.).

In general, there was very little difference in the early vegetation dynamics in 1990 among species of forage sown. In the second growing season differences in development were expressed. The clovers developed more rapidly than seeded grasses; clovers produced 50% greater vegetative cover, and 282% greater forage production than the seeded grasses in 1991. Thirty-nine percent of the variability in total vegetative cover in 1990 was due to the clovers, compared to the combined variability of 18% contributed by the orchardgrass and smooth bromegrass. Thirty-one percent of the variability in total cover, and 59% of the variability in vegetative cover was accounted for by the clovers during the 1991 growing season. During this same period the combined contribution of the seeded grasses was 12% of total cover and 22% of vegetative cover.

Of the seeded grasses, orchardgrass was the most rapid in its development. Orchardgrass had 535% greater production than smooth bromegrass in 1990, and smooth brome

had 62% lower density than orchardgrass in 1991. During the 1991 growing season smooth bromegrass contributed almost no variability in either total cover or vegetative cover.

These data are consistent with generally held assumptions that alsike clover is rapid in its development, and smooth bromegrass establishes more slowly.

5.1.3. Plant Growth and Non-floristic Cover Components

The early development of some the seeded herbaceous plant species, in particular the clovers, was firmly correlated to the cover of the non-floristic cover components: wood, undecomposed plant litter and bare mineral soil. The growth and survival of lodgepole pine, however, was not correlated ($P>0.05$) with any of the non-floristic cover components.

Alsike clover had the closest relationship between its dynamics and the initial cover of the non-floristic cover components, in particular the initial cover of wood. All of the dynamics parameters (vegetative cover, density, height, and production) on plots sown to alsike clover were positively correlated with the initial cover of wood on those plots at some time during the first two growing seasons.

Total vegetative cover on plots sown to alsike clover increased with increasing cover of wood in both 1990 ($r^2=0.26$, $P<0.02$), and 1991 ($r^2=0.18$, $P<0.06$). Density of vegetation on plots sown to alsike clover was partially

explained by the pure live seeding rate in 1990 (r^2=0.21, P<0.04); however, the inclusion of the initial cover of wood in the correlation model explained 51% more of the variability in density during this period (R^2=0.72, P<0.001). During the second growing season density of vegetation on alsike clover plots was not linearly related to seeding rate, although, cover of wood explained 36% (P<0.005) of the variability in density. Height of vegetation on alsike clover plots was also correlated to the cover of bare mineral soil and wood in 1990 (R^2=0.33, P<0.04), and with wood alone (r^2=0.37, P<0.004) in 1991. Production also displayed a positive relationship with the cover of wood; in 1990 it was correlated with litter and wood (R^2=0.65, P<0.001) and with wood alone (r^2=0.20, P<0.05) in 1991.

The association between the vegetation dynamics of plots sown to alsike clover and the cover of wood on these plots might be explained by the wood's ability to trap moisture the surface horizon of the soil immediately beneath it. Alsike clover is known to grow best where soil moisture is abundant (Heath *et al.* 1973: 157, Walton 1983: 86). The incremental moisture associated from additional wood could explain the increases in vegetative cover, density, height and production of the alsike clover dominated plots.

5.2. Two-Dimensional Partitioning

Determining the influence of treatments on multivariate systems, where more than one dependent response variable is of interest, has always presented a challenge to find the appropriate statistical analysis. Traditionally, and inappropriately, multivariate data have been divided into a series of univariate data sets, in which each dependent variable was analyzed alone with the independent variable(s) by a method such as the univariate analysis of variance (ANOVA). This approach seriously inflates the probability of a type I error.

Changes in botanical composition, as reflected in differences in the cover of different species or species groups, is an example of a multivariate system that presents difficulties in analyzing the data. Moreover, analysis of these data are further complicated because the response variables are highly correlated. Stroup and Stubbendieck (1983) cited similar difficulties in analyzing changes in botanical composition, and suggested the application of the multivariate analysis of variance (MANOVA).

Two-dimensional partitioning of variation (TDP) provides another feasible alternative for additive multivariate data sets. TDP is not just an alternative method of computing well-known statistics, it is an extended framework from which to study multivariate systems and their relationships to their components, while simultaneously

determining the effect of treatments on all components. It provides the analysis to detect "which treatment effects on yield components are treatment effects on yield" (Eaton *et al*. 1986).

TDP was originally applied to horticultural applications in which treatment effects on total plant yield, and the constituent plant parts contributing to yield (yield components) were monitored (Eaton *et al*. 1986). It evolved as an extension to sequential yield component analysis (Eaton and Kyte 1978) and sequential plant growth analysis (Jolliffe *et al*. 1982). It provided the analytical framework from which to assess how carbohydrate production (total yield) was partitioned among the components contributing to yield (*e.g*. stems, leaves, flowers, fruit), and how treatments influenced the components, and, therefore, ultimately total yield. TDP has also been applied to data which are transformed into an additive system (Hesketh *et al*. 1990).

TDP is advantageous, in that it utilizes two common statistical techniques, linear regression and ANOVA, with results that are readily interpretable by the researcher.

TDP assumes multicollinearity among the dependent variables being assessed. That is total cover, or total vegetative cover, is assumed to be the sum of individual cover components. Moreover, the value of the cover components is assumed to be influenced directly by the value

of the other components. The first step of TDP is to remove this collinearity through linear multiple regression. As each component is added into the multiple regression model the variability explained by the regression line is removed, hence, removing any of the codependence contained in the variables being regressed. The residuals are retained and the newly orthogonalized variables are then collectively regressed against the next unorthogonalized variable entered in the model. The residual values of the components which are used in the final multiple regression vary in the same proportions as the unorthogonalized data. After orthogonalization is achieved the data are used to calculate the amount of variability contributed by each of the dependent response variables by regressing total cover (or total vegetative cover) on each of its constituent cover component's residuals. The value of the constituent cover component's contribution to total variability is equal to the simple regression coefficient for that variable in the multiple regression model. Alternatively, the cover component's contribution can be calculated by the increment in the partial regression coefficient resulting from adding the cover component into the multiple regression model.

One weakness in the application of the TDP approach to plant dynamics is that the value of the simple regression coefficients will vary depending on the order in which the cover components are entered into the multiple regression

model during the orthogonalization procedure. Therefore, the placement of the constituent components in the model should have an developmental basis or other biological significance to guide their ordering. Often the order will not be readily apparent, and the investigator will have to arrange the variables in groups, or enter them in batches. Care should be taken, therefore, not to place too much emphasis on the absolute values for a given component's contribution to total variability if the variables are entered in groups.

The second dimension of TDP is a simple analysis of variance on each of the cover components. The value for total sum of squares is substituted with the percent variability that the cover component contributes to total variability. The proportions between the sum of squares for treatment and error, and total sum of squares are used to calculate the ANOVA based on contribution to variability in total cover (Tables 9 to 12).

The power of TDP is in its ability to detect treatment effects on components of the multivariate system and simultaneously compare these responses to the treatment effect on the system as a whole. In effect, the variability in total cover (or total vegetative cover) is partitioned such that the components which are influenced by treatment can be identified, and how they in turn contribute to the response of total cover to treatment.

In this experiment total cover, or spatial area, was partitioned into various cover components contributing to that spatial arrangement. These cover components are a bioassay for the general dynamics of the plant population on the site.

TDP is suitable for other applications where treatment effects on the components of an additive system, and the system as a whole are of interest. For example, total dry matter production of a mixed stand can be attributed to each of the individual species of plants contributing to production.

5.3. Lodgepole Pine Growth and Survival

5.3.1. Lodgepole Pine Damage and Survival

The early conifer survival on this site was not influenced by forage seeding. Winter damage on the lodgepole pine induced by rodents was positively related to the seeding of orchardgrass, although the lodgepole pine survival was independent of rodent damage. It is uncertain why there was a strong linear relationship between orchardgrass vegetative cover and rodent damage on lodgepole pine, and not a similar response with the other forage species seeded on the site. It is possible that the rodents prefered orchardgrass as a source of visual cover and food.

5.3.2. Lodgepole Pine Growth

Lodgepole pine height and basal diameter growth were unaffected by the orchardgrass, smooth bromegrass, alsike clover, and the forage mixture seeding treatments.

Lodgepole pine seedlings were overtopped by all seeded vegetation in the second growing season; however, they remained taller than the native vegetation controls during both growing seasons. The height of the herbaceous vegetation possibly influenced the competition for light on the site. One possible expression of the competition for light was in the ratio of lodgepole pine unit needle mass at the end of the second growing season to the unit needle mass at the beginning of the second growing season. Unit needle mass growth ratio for lodgepole pine with competing vegetation increased slightly, while lodgepole pine with no competition had, on average, only two-thirds the unit needle mass at the end of the growing season that they had at the beginning of the growing season. These data contradict the assumption that competing vegetation should decrease needle mass.

Height of lodgepole pine with surrounding vegetation was on average 14% shorter than conifers with no competition at the end of the second growing season. There were no differences in the height growth of lodgepole pine, however, due to species of forage sown, nor were there difference expressed between seeded and native vegetation. Even though

there were significant differences in the density, height, production, and cover of vegetation surrounding the lodgepole pine, these differences in surrounding vegetation were not manifested in differences in tree growth. Moreover, these differences in vegetation surrounding the lodgepole pine did not effect the ratio of needle masses over the second growing season. This contradicts the findings of Trowbridge and Holl (1992) who reported the needle mass of lodgepole pine two years after planting and seeded with alsike clover was less ($P<0.05$) than plots with native vegetation alone.

Conifer basal diameter growth was also unaffected by the seeding rate of forages. In the second growing season (1991) there were very weak linear relationships between decreases in the growth of basal diameter and increasing seeding rate.

Both conifer height growth and basal diameter growth were negatively correlated to vegetation production in 1990 on plots sown to orchardgrass, and positively associated with increases in density and vegetative cover on plots sown to alsike clover in 1991. No explanation as to why these variable combinations were of importance was determined.

5.4. Management Recommendations

These data indicate that forage species selection and seeding rate will not greatly influence the very early growth and survival of planted lodgepole pine in the Very Dry, Cool Montane Spruce biogeoclimatic subzone, and should not impede the Ministry of Forests objective of achieving a minimum lodgepole pine stocking rate of 1100 stems/ha, 12 - 15 years after planting. These results, however, give no indication of the medium and long-term influence of forage seeding on lodgepole pine growth and survival, and must be considered within the context of the whole process from planting of conifers and the seeding of forages to the free-to-grow stage in the lodgepole pine.

If rodent damage is of concern, eliminating orchardgrass from operational seeding should be considered; rodent damage was positively associated with the vegetative cover of orchardgrass. Reduction of the seeding rate of orchardgrass or a decreased percent composition in the seeding mix should also reduce the potential for rodent induced damage on the conifers.

Concurrent planting of conifers and seeding of forages has produced favourable results. It is conjectured that planting conifers into an established forage stand would have resulted in lower survival and lower growth rates in the lodgepole pine.

6. Literature Cited

Anderson, C.H., and C.R. Elliot. 1957. Studies on the establishment of cultivated grasses and legumes on burned-over land in northern Canada. Can. J. Plant Sci. 37:97-101.

Association of Official Seed Analysts. 1978. Rules for testing seeds. J. Seed Technol. 3:29-35, 39-40, 49-50.

Baron, F.J. 1962. Effects of different grasses on ponderosa pine seedling establishment. U.S.D.A. Forest Serv., Res. Note PSW-199.

Bergerud, W. 1989. ANOVA: Factorial designs with a separate control. Biometrics Information Pamphlet No. 14, B.C. Minist. of Forests Lands, Victoria, B.C.

Berglund, E.R. 1976. Seeding to control erosion along forest roads. Ext. Circ. No. 885. Oreg. St. Univ., Corvallis, Oreg.

Brooke, B.M. and F.B. Holl. 1988. Establishment of winter versus spring aerial seedings of domestic grasses and legumes on logged winter sites. J. Range Manage. 41:53-57.

Carr, W.W. 1980. A handbook for forest roadside erosion control in British Columbia. Land Manage. Report No. 4, B.C. Minist. of Forests, Victoria, B.C.

Christ, J.H. 1934. Reseeding burned-over lands in northern Idaho. Agr. Exp. Sta. Bull. No. 201. Univ. Idaho, Moscow, Idaho.

Clark, M.B., and A. McLean. 1975. Growth of lodgepole pine seedlings in competition with different densities of grass. B.C. Forest. Serv., Res. Note 70, Victoria, B.C.

Clark, M.B., and A. McLean. 1979. Growth of lodgepole pine in competition with grass. B.C. Forest Serv., Res. Note 86, Victoria, B.C.

Daubenmire, R. 1959. A canopy coverage method of vegetational analysis. Northwest Sci. 33:43-64.

Eaton, G.W., P.A. Bowen, and P.A. Jolliffe. 1986. Two-dimensional partitioning of yield variation. HortSci. 21:1052-1053.

Eaton, G.W., and T.R. Kyte. 1978. Yield component analysis in the cranberry. J. Amer. Soc. Sci. 103:578-583.

Eddleman, L. and A. McLean. 1969. Herbage - its production and use within the coniferous forest. Pages 179-196 *in* Coniferous forests of the northern rocky mountains: Proc. of the 1968 symp. Centre for Natur. Resour., Univ. Mont., Missoula, Mont.

Eissenstat, D.M. 1980. Water competition and animal damage in a grass seeded Douglas-fir plantation. M.Sc. Thesis. Univ. of Idaho, Moscow, Idaho.

Eissenstat, D.M., and J.E. Mitchell. 1983. Effects of seeding grass and clover on growth and water potential of Douglas-fir seedlings. Forest Sci. 29:166-179.

Elliot, K.J., and A.S. White. 1987. Competitive effects of various grasses and forbs on ponderosa pine seedlings. Forest Sci. 33(2):156-166.

Heath, M.E., D.S. Metcalfe, and R.E. Barnes. 1973. Forages: The science of grassland agriculture. Iowa St. Univ. Press, Ames, Iowa.

Hesketh, J.L., G.W. Eaton, and T.E. Baumann. 1990. Strawberry plant spacing on raised beds. Fruit Var. J. 44:12-17.

Hope, G.D., W.R. Mitchell, D.A. Lloyd, W.L. Harper, and B.M. Wikeem. 1991. Montane spruce zone. Pages 183-194 *in* D. Meidinger, and J. Pojar, eds. Ecosystems of British Columbia. Research Branch, B.C. Ministr. Forest, Victoria, B.C.

Jolliffe, P.A., G.W. Eaton, and J. Lovett Doust. 1982. Sequential analysis of plant growth. New Phytologist 92:287-296.

Klinger, G.E. 1986. Effects of grass legume competition on shrub and hardwood invasion in newly harvested clear-cuts. M.Sc. Thesis (Forest Resour.), Univ. Wash., Pullman, Wash.

Klock, G.O., A.R. Tiedemann, and W. Lopushinsky. 1975. Seeding recommendations for disturbed mountain slopes in north-central Washington. Res. Note PNW-244. U.S.D.A. Forest Serv.

Krueger, W.C. 1983. Cattle grazing in managed forests. Pages 24-41, *in* B.F. Roche Jr., and D.M. Baumgartner, eds. Forestland grazing. Wash. St. Univ., Pullman, Wash.

McLean, A., and A.H. Bawtree. 1971. Seeding forest rangeland in British Columbia. Can. Dept. of Agr. Pub. No. 1463, Ottawa, Ont.

McLean, A., and M.B. Clark. 1980. Grass, trees and cattle on clear-cut logged areas. J. Range Manage. 33:213-217.

Newman, R., M.D. Pitt, D. Quinton, B. Wikeem, and P. Youwe. 1989. The effects of cattle grazing, forage seeding, basal scarring and leader damage on forest regeneration. Working plan. B.C. Minist. Forest, Intern. Rep., Kamloops, B.C.

Nordstrom, L.O. 1984. The ecology and management of forest range in British Columbia: A review and analysis. B.C. Forest Serv., Land Manage. Rep. 19. Victoria, B.C.

Pickford, G.D., and E.R. Jackman. 1944. Reseeding eastern Oregon summer ranges. Circ. No. 159, Agr. Expt. Stat., Oreg. St. College, Corvallis, Oreg.

Pitt, M.D. 1989. Integrated Forest/Range Research Five Year Plan. Forest. Can. and B.C. Minist. Forest, Joint pub. Governments of Can. and B.C., Victoria, B.C.

Pringle, W.L., and A. McLean. 1962. Seeding forest ranges in the dry belt of British Columbia. Can. Dept. Agr. Pub. No. 1147, Ottawa, Ont.

Quinton, D.A. 1984. Cattle diets on seeded clear-cut areas in central interior British Columbia. J. Range Manage. 37:349-352.

Silvertown, J. 1987. Introduction to plant population ecology. John Wiley and Sons, Inc., New York.

Squire, R.D. 1977. Interacting effects of grass competition, fertilizing and cultivation on the early growth of Pinus radiata, D. Don. Aust. Forest Res. 7:247-252.

Stroup, W.W., and J. Stubbendieck. 1983. Multivariate statistical methods to determine changes in botanical composition. J. Range Manage. 36:208-212.

Sullivan, T.P., and D.S. Sullivan. 1984. Influence of range seeding on rodent populations in the interior of British Columbia. J. Range Manage. 37:163-165.

Trowbridge, R., and F.B. Holl. 1992. Early growth of lodgepole pine after establishment of alsike clover-*Rhizobium* nitrogen-fixing symbiosis. Can J. Forest Res. (in press).

Walton P.D. 1983. Production and management of cultivated forages. Reston Publishing Co., Reston, Virginia.

Appendix 1. Cover Categories for Two-Dimesional Partitioning.

Cover category	Code	Cover components
Litter/wood	LTWD	Undecomposed leaf litter, humus. Wood.
Soil	SOIL	Bare mineral soil.
Smooth bromegrass	BRIN	*Bromus inermus* Leys.
Orchardgrass	DAGL	*Dactylis glomerata* L.
Clovers	TRSP	*Trifolium hybridum* L. *Trifolium repens* L.
Native graminoids	GRAS	*Calamagrostis rubescens* Buckl. *Carix richardsonii* L. *Luzula hitchcockii* Hamet-Ahti
Native forbs	FORB	*Arnica cordifolia* Hook. *Cornus canadensis* L. *Epilobium angustifolium* L. *Epilobium paniculatum* Nutt. *Equisetum scirpoides* Michx. *Petasites palmatus* (Ait.) Cronq. *Taraxacum officinale* Weber
Native shrubs	SHRB	*Arctostaphylos uva-ursi* L. *Linnaea borealis* L. *Lonicera involucrata* *Vaccinium scoparium* Leiberg *Ribes lacustre* (Pers.) Poir.

Appendix 2. Weather Summary for Tunkwa Lake Research Site in 1990 and 1991.

Weather Data 1990

	SOIL TEMPERATURE (C)						SOIL MOISTURE (BARS)				
	2.5cm		10.0cm		AIR TEMP (C)		2.5cm		10.0cm		
DATE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	PRECIP. (mm)
24-Apr	10.4	0.8	10.4	2.5	10.2	-2.4	>15.00	>15.00	>15.00	>15.00	11.0
25-Apr	0.8	0.0	2.7	1.1	2.4	-3.8	1.55	>15.00	1.26	>15.00	6.0
26-Apr	4.1	0.2	1.8	0.9	4.3	-3.6	1.85	2.00	1.55	1.67	3.0
27-Apr	1.4	-0.1	1.4	0.7	2.3	-6.2	1.88	2.08	1.56	1.67	1.0
28-Apr	0.8	0.1	0.8	0.6	0.7	-5.1	1.92	2.01	1.57	1.61	1.0
29-Apr	5.8	-0.1	1.6	0.4	3.9	-4.5	1.85	2.06	1.54	1.65	0.0
30-Apr	10.6	0.0	3.1	0.6	12.1	0.2	1.72	2.04	1.49	1.64	0.0
01-May	7.4	1.6	3.7	1.9	7.6	2.6	1.74	1.88	1.49	1.57	2.0
02-May	12.1	2.1	5.3	2.6	11.9	1.6	1.66	1.84	1.46	1.54	0.0
03-May	9.6	2.3	5.3	3.2	12.6	1.5	1.72	1.85	1.49	1.55	0.0
04-May	16.8	2.3	7.8	3.5	19.8	3.1	1.62	1.87	1.45	1.57	0.0
05-May	14.9	4.1	7.9	5.1	19.9	0.9	1.67	1.88	1.50	1.59	0.0
06-May	9.3	1.2	6.6	3.6	4.7	-3.8	1.84	2.02	1.59	1.69	0.0
07-May	8.3	1.4	4.5	3.1	4.1	-3.9	1.83	2.03	1.64	1.73	1.0
08-May	13.8	1.2	5.8	2.7	9.9	-1.6	1.72	1.99	1.56	1.70	2.0
09-May	10.4	2.6	5.6	3.7	10.8	1.8	1.78	1.93	1.57	1.64	0.0
10-May	10.5	3.7	5.9	4.3	10.1	1.0	1.75	1.91	1.55	1.63	2.0
11-May	10.7	2.7	5.8	4.0	8.5	1.1	1.72	1.87	1.54	1.60	1.0
12-May	9.3	2.1	5.5	3.9	7.3	0.1	1.77	1.90	1.55	1.61	0.0
13-May	6.9	2.2	5.0	3.8	4.6	-0.4	1.74	1.90	1.52	1.62	5.0
14-May	10.1	1.7	5.3	3.1	8.4	0.0	1.68	1.85	1.45	1.54	3.0
15-May	11.3	1.6	5.9	3.2	11.4	1.6	1.71	1.88	1.45	1.53	1.0
16-May	10.8	1.9	5.8	3.7	9.5	0.4	1.71	1.88	1.45	1.53	2.0
17-May	9.7	3.0	5.5	4.3	8.5	1.0	1.67	1.79	1.40	1.47	6.0
18-May	11.3	3.0	6.2	4.1	8.4	0.5	1.65	1.79	1.37	1.42	3.0
19-May	11.5	2.0	6.3	3.9	12.0	-0.7	1.66	1.84	1.37	1.43	1.0
20-May	6.6	2.2	5.8	4.2	5.3	-0.6	1.68	1.83	1.33	1.44	8.0
21-May	11.5	1.2	6.3	3.2	11.6	-1.6	1.64	1.87	1.37	1.44	0.0
22-May	7.9	3.4	5.8	4.7	6.5	1.0	1.69	1.79	1.40	1.44	2.0
23-May	10.7	1.5	5.8	3.8	8.7	-1.9	1.68	1.88	1.37	1.48	7.0
24-May	6.7	3.4	5.0	4.3	4.2	0.9	1.67	1.75	1.30	1.39	11.0
25-May	8.0	3.0	5.1	4.2	4.6	1.3	1.68	1.79	1.36	1.40	8.0
26-May	11.2	2.8	6.4	4.4	11.6	0.6	1.66	1.82	1.36	1.43	1.0
27-May	10.8	4.7	6.9	5.3	12.4	5.6	1.68	1.80	1.43	1.48	3.0
28-May	10.6	6.6	7.3	6.2	9.9	4.8	1.64	1.73	1.33	1.46	8.0
29-May	11.7	5.8	7.6	6.2	10.3	3.7	1.61	1.74	1.31	1.38	2.0
30-May	15.2	3.3	8.2	5.7	14.0	0.6	1.63	1.82	1.38	1.48	0.0
31-May	9.7	4.0	7.5	6.1	9.9	1.5	1.68	1.85	1.43	1.51	7.0
01-Jun	10.9	2.9	7.2	5.3	10.9	0.3	1.71	1.85	1.47	1.52	1.0
02-Jun	13.3	5.1	8.0	6.0	13.5	3.6	1.68	1.83	1.47	1.52	0.0
03-Jun	9.9	4.9	7.3	6.1	9.9	3.2	1.73	1.85	1.48	1.53	4.0
04-Jun	10.4	3.4	6.9	5.4	8.1	0.6	1.76	1.90	1.50	1.54	1.0
05-Jun	11.4	1.9	7.2	4.7	12.8	-2.2	1.75	1.97	1.51	1.59	0.0
06-Jun	11.0	2.6	7.3	5.1	12.2	1.6	1.68	1.95	1.48	1.59	7.0
07-Jun	17.0	3.7	8.6	5.6	11.8	1.5	1.67	1.88	1.45	1.53	0.0

Weather Data 1990

	SOIL TEMPERATURE (C)						SOIL MOISTURE (BARS)				
	2.5cm		10.0cm		AIR TEMP (C)		2.5cm		10.0cm		PRECIP.
DATE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	(mm)
08-Jun	10.0	3.1	7.4	5.6	9.9	1.2	1.79	1.92	1.51	1.55	0.0
09-Jun	10.6	4.6	7.6	5.9	10.9	3.6	1.62	1.90	1.37	1.56	17.0
10-Jun	8.5	4.0	7.4	6.3	6.3	0.3	1.64	1.74	1.33	1.39	3.0
11-Jun	6.0	2.7	6.3	4.9	7.2	0.4	1.71	1.80	1.37	1.50	6.0
12-Jun	7.8	2.9	5.6	4.6	3.6	1.3	1.69	1.84	1.34	1.40	7.0
13-Jun	15.4	4.6	8.0	5.3	13.3	1.6	1.61	1.79	1.31	1.42	0.0
14-Jun	18.9	5.5	9.9	6.5	18.9	4.1	1.58	1.81	1.40	1.43	0.0
15-Jun	18.7	7.1	10.6	7.7	19.0	9.2	1.61	1.80	1.42	1.49	0.0
16-Jun	13.2	8.5	9.9	8.5	13.0	6.4	1.53	1.78	1.30	1.46	19.0
17-Jun	19.2	6.2	10.5	7.6	17.5	4.5	1.49	1.67	1.27	1.38	0.0
18-Jun	13.8	8.2	9.9	8.5	13.6	5.4	1.55	1.69	1.36	1.44	7.0
19-Jun	14.2	7.2	9.8	8.1	13.8	6.1	1.58	1.69	1.39	1.44	0.0
20-Jun	15.6	7.8	10.3	8.4	15.6	6.0	1.58	1.72	1.41	1.46	0.0
21-Jun	21.4	7.1	12.2	8.5	20.9	6.0	1.53	1.75	1.39	1.48	0.0
22-Jun	20.1	9.3	12.7	10.1	25.2	10.7	1.58	1.72	1.40	1.47	1.0
23-Jun	19.0	10.1	12.9	10.6	21.5	9.4	1.60	1.74	1.44	1.49	0.0
24-Jun	17.5	9.1	12.4	10.5	19.7	7.9	1.66	1.80	1.49	1.54	0.0
25-Jun	17.2	8.5	12.2	10.3	17.9	7.4	1.71	1.88	1.54	1.61	0.0
26-Jun	17.0	7.9	12.0	9.9	17.0	5.2	1.78	1.93	1.61	1.67	0.0
27-Jun	16.3	7.3	11.7	9.7	17.0	4.3	1.84	2.01	1.67	1.71	0.0
28-Jun	16.0	8.4	11.4	9.8	15.9	5.0	1.90	2.08	1.71	1.76	0.0
29-Jun	16.1	7.6	11.7	9.5	18.8	4.3	1.95	2.11	1.75	1.80	0.0
30-Jun	17.4	9.5	12.1	10.3	16.7	6.0	2.00	2.22	1.78	1.84	0.0
01-Jul	17.2	7.8	12.0	9.7	15.2	4.6	2.08	2.29	1.84	1.89	0.0
02-Jul	11.8	8.2	11.4	10.0	8.2	3.1	1.82	2.27	1.84	1.90	8.0
03-Jul	12.3	6.2	10.1	8.6	13.6	2.5	1.82	1.97	1.82	1.89	0.0
04-Jul	16.6	6.7	11.5	8.6	19.4	4.3	1.81	1.99	1.78	1.87	0.0
05-Jul	15.5	8.9	11.5	9.9	18.7	6.3	1.84	2.01	1.77	1.84	4.0
06-Jul	11.2	9.1	11.0	9.8	7.8	5.0	1.58	1.85	1.43	1.78	37.0
07-Jul	14.8	8.8	11.0	9.3	15.8	4.6	1.64	1.76	1.39	1.44	0.0
08-Jul	16.7	8.3	11.9	9.7	20.4	5.8	1.59	1.72	1.39	1.44	0.0
09-Jul	17.5	8.9	12.4	10.2	21.3	6.7	1.60	1.72	1.42	1.46	0.0
10-Jul	20.1	9.6	13.6	10.7	26.2	8.7	1.59	1.73	1.44	1.48	0.0
11-Jul	21.2	11.1	14.3	11.8	27.7	12.7	1.63	1.74	1.47	1.52	0.0
12-Jul	21.1	12.9	14.6	12.6	25.8	12.5	1.64	1.80	1.52	1.58	2.0
13-Jul	19.3	10.3	14.0	12.1	21.9	8.6	1.79	1.92	1.58	1.66	0.0
14-Jul	19.9	10.0	14.0	11.9	22.3	10.7	1.88	2.06	1.66	1.76	0.0
15-Jul	20.7	9.6	14.1	11.7	24.2	9.4	2.01	2.29	1.76	1.85	0.0
16-Jul	18.6	10.8	13.6	12.1	19.7	8.7	2.29	2.85	1.84	1.95	0.0
17-Jul	15.4	8.9	12.9	11.3	16.6	7.2	2.85	3.44	1.95	2.01	0.0
18-Jul	14.9	8.4	12.0	10.7	16.2	5.2	3.44	4.26	2.01	2.08	4.0
19-Jul	17.6	8.9	12.6	10.6	18.5	7.7	4.27	5.91	2.08	2.21	0.0
20-Jul	19.6	8.1	13.1	10.4	20.6	6.9	5.93	9.16	2.21	2.73	0.0
21-Jul	18.1	8.6	13.0	10.7	23.9	8.5	9.16	14.22	2.73	4.87	0.0
22-Jul	21.3	9.8	14.0	11.2	25.8	10.5	14.19	24.61	4.88	12.94	0.0
23-Jul	16.2	11.7	13.3	12.2	20.3	10.3	2.25	27.38	12.94	20.93	8.0
24-Jul	13.4	10.7	12.3	11.4	13.6	7.3	1.98	2.26	11.78	20.13	3.0
25-Jul	17.4	10.9	14.3	11.1	20.8	8.7	1.55	2.01	2.14	11.78	25.0

Weather Data 1990

DATE	SOIL TEMPERATURE (C) 2.5cm MAX	2.5cm MIN	10.0cm MAX	10.0cm MIN	AIR TEMP (C) MAX	AIR TEMP (C) MIN	SOIL MOISTURE (BARS) 2.5cm MAX	2.5cm MIN	10.0cm MAX	10.0cm MIN	PRECIP. (mm)
26-Jul	18.4	11.7	13.9	12.0	22.6	12.5	1.72	1.90	1.96	2.14	0.0
27-Jul	17.6	11.1	13.5	12.1	19.9	10.2	1.90	2.08	1.97	2.08	0.0
28-Jul	18.7	9.8	13.6	11.5	22.4	10.4	2.04	2.22	2.03	2.09	0.0
29-Jul	19.4	9.9	13.9	11.6	24.9	10.2	2.18	2.39	2.09	2.13	0.0
30-Jul	18.8	12.0	13.9	12.2	25.3	11.6	2.39	2.68	2.13	2.25	0.0
31-Jul	18.6	10.7	14.1	12.1	24.3	7.4	2.27	2.56	2.23	2.37	1.0
01-Aug	18.2	11.6	14.0	12.4	20.4	11.6	2.45	2.81	2.37	2.78	0.0
02-Aug	15.6	9.8	13.3	11.6	20.2	8.7	2.81	3.92	2.78	4.69	0.0
03-Aug	15.9	9.4	13.0	11.4	21.7	9.7	3.92	6.38	4.69	15.00	0.0
04-Aug	20.1	9.9	14.0	11.4	25.4	9.6	6.38	12.36	>15.00	>15.00	0.0
05-Aug	19.9	11.7	14.3	12.3	27.2	14.1	12.36	>15.00	>15.00	>15.00	0.0
06-Aug	20.5	11.5	14.5	12.5	22.0	11.3	>15.00	>15.00	>15.00	15.00	0.0
07-Aug	20.2	9.7	14.2	11.9	23.7	6.5	>15.00	>15.00	>15.00	>15.00	0.0
08-Aug	21.9	9.9	14.6	11.9	25.7	9.4	>15.00	>15.00	>15.00	>15.00	0.0
09-Aug	23.1	10.5	15.0	12.1	25.8	13.1	>15.00	>15.00	>15.00	>15.00	0.0
10-Aug	23.2	11.7	15.5	12.6	26.4	15.9	>15.00	>15.00	>15.00	>15.00	0.0
11-Aug	22.8	12.8	15.6	13.1	26.0	13.6	>15.00	>15.00	>15.00	>15.00	0.0
12-Aug	23.9	12.1	16.0	13.1	27.1	13.1	>15.00	>15.00	>15.00	>15.00	0.0
13-Aug	23.4	13.1	16.1	13.6	25.7	13.4	>15.00	>15.00	>15.00	>15.00	0.0
14-Aug	23.5	10.5	15.6	12.9	24.1	7.5	>15.00	>15.00	>15.00	>15.00	0.0
15-Aug	23.5	11.3	15.6	12.7	22.6	10.7	>15.00	>15.00	>15.00	>15.00	0.0
16-Aug	16.2	11.2	14.4	12.7	16.7	8.5	>15.00	>15.00	>15.00	>15.00	0.0
17-Aug	17.5	8.8	13.2	11.7	18.6	6.9	>15.00	>15.00	>15.00	>15.00	5.0
18-Aug	15.7	8.9	12.5	11.3	15.6	5.5	>15.00	>15.00	>15.00	>15.00	5.0
19-Aug	20.2	8.7	13.7	10.8	20.6	7.3	5.38	>15.00	>15.00	>15.00	0.0
20-Aug	20.6	11.9	14.6	12.1	24.2	15.2	4.33	5.61	>15.00	>15.00	0.0
21-Aug	16.8	12.6	14.0	12.8	19.3	8.5	4.63	5.28	>15.00	>15.00	4.0
22-Aug	17.8	9.1	13.5	12.0	16.3	3.0	2.61	4.63	>15.00	>15.00	3.0
23-Aug	11.6	6.1	12.1	10.1	10.0	1.3	2.47	2.70	>15.00	>15.00	1.0
24-Aug	12.0	5.9	10.4	9.0	10.8	2.1	2.24	2.63	>15.00	>15.00	1.0
25-Aug	9.7	6.4	9.8	8.7	6.4	1.5	1.93	2.41	>15.00	>15.00	5.0
26-Aug	10.8	5.8	9.5	8.2	11.5	1.3	2.05	2.23	>15.00	>15.00	0.0
27-Aug	16.2	4.8	10.9	7.8	16.9	1.3	2.12	2.42	>15.00	>15.00	0.0
28-Aug	17.0	6.4	11.5	8.7	19.7	5.6	2.29	2.54	13.43	>15.00	0.0
29-Aug	13.3	8.5	10.7	9.7	15.8	5.6	2.47	2.61	11.93	13.43	4.0
30-Aug	14.2	7.4	10.7	9.2	13.6	4.3	2.34	2.52	10.88	11.99	0.0
31-Aug	14.6	6.6	10.6	8.9	13.0	2.8	2.41	2.64	10.33	10.93	1.0
01-Sep	13.4	6.0	10.1	8.5	13.8	3.1	2.51	2.73	10.65	11.07	0.0
02-Sep	13.5	5.0	10.2	8.0	15.1	2.9	2.58	2.86	11.07	11.78	0.0
03-Sep	15.8	5.1	10.4	8.1	14.8	4.2	2.64	3.01	11.78	14.14	0.0
04-Sep	17.1	3.7	10.5	7.4	20.4	1.4	2.78	3.22	14.14	>15.00	0.0
05-Sep	18.5	5.6	11.3	8.3	21.7	6.2	3.22	4.47	>15.00	>15.00	0.0
06-Sep	19.5	7.3	11.9	9.1	22.4	7.1	4.50	11.30	>15.00	>15.00	0.0
07-Sep	20.1	7.9	12.3	9.5	23.9	9.3	11.30	>15.00	>15.00	>15.00	0.0
08-Sep	17.7	9.7	12.3	10.4	22.9	12.0	>15.00	>15.00	>15.00	>15.00	0.0
09-Sep	19.5	7.8	12.5	10.0	22.2	8.8	>15.00	>15.00	>15.00	>15.00	0.0
10-Sep	20.1	7.8	12.6	9.9	23.3	7.7	>15.00	>15.00	>15.00	>15.00	0.0
11-Sep	19.9	7.6	12.5	9.8	22.2	8.4	>15.00	>15.00	>15.00	>15.00	0.0

Weather Data 1990

	SOIL TEMPERATURE (C)				AIR TEMP (C)		SOIL MOISTURE (BARS)				
	2.5cm		10.0cm				2.5cm		10.0cm		
DATE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	PRECIP. (mm)
12-Sep	14.7	6.9	11.5	10.1	15.3	6.7	>15.00	>15.00	>15.00	>15.00	0.0
13-Sep	18.2	5.1	11.3	8.5	19.6	2.7	>15.00	>15.00	>15.00	>15.00	0.0
14-Sep	18.9	5.7	11.5	8.6	21.1	4.9	>15.00	>15.00	>15.00	>15.00	0.0
15-Sep	15.7	7.1	10.9	9.2	18.6	7.3	>15.00	>15.00	>15.00	>15.00	0.0
16-Sep	11.4	7.4	10.2	9.3	10.5	4.9	>15.00	>15.00	>15.00	>15.00	0.0
17-Sep	13.4	5.1	9.8	8.1	16.8	2.5	>15.00	>15.00	>15.00	>15.00	0.0
18-Sep	15.3	6.0	10.4	8.2	16.6	6.4	>15.00	>15.00	>15.00	>15.00	0.0
19-Sep	15.9	5.6	10.2	8.3	12.9	5.1	>15.00	>15.00	>15.00	>15.00	0.0
20-Sep	16.5	4.3	10.3	7.5	17.0	6.0	>15.00	>15.00	>15.00	>15.00	0.0
21-Sep	18.3	7.9	11.3	8.9	18.6	7.7	>15.00	>15.00	>15.00	>15.00	0.0
22-Sep	18.3	7.0	11.4	8.9	22.4	7.0	>15.00	>15.00	>15.00	>15.00	0.0
23-Sep	19.6	8.4	12.1	9.5	22.5	10.9	>15.00	>15.00	>15.00	>15.00	0.0
24-Sep	18.6	7.6	11.9	9.5	23.5	7.5	>15.00	>15.00	>15.00	>15.00	0.0
25-Sep	17.3	6.7	11.5	9.4	16.5	6.7	>15.00	>15.00	>15.00	>15.00	0.0
26-Sep	16.1	3.4	10.3	7.8	17.1	3.6	>15.00	>15.00	>15.00	>15.00	0.0
27-Sep	15.2	2.7	9.7	7.1	16.8	3.9	>15.00	>15.00	>15.00	>15.00	0.0
28-Sep	11.2	5.9	9.2	7.8	16.1	8.8	>15.00	>15.00	>15.00	>15.00	0.0
29-Sep	12.6	5.3	9.3	8.2	11.2	1.3	>15.00	>15.00	>15.00	>15.00	0.0
30-Sep	12.9	2.9	8.9	6.8	13.3	-0.1	>15.00	>15.00	>15.00	>15.00	0.0

Weather Data 1991

	SOIL TEMPERATURE (C)				AIR TEMP (C)		SOIL MOISTURE (BARS)				
	2.5cm		10.0cm				2.5cm		10.0cm		PRECIP
DATE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	(mm)
15-May	12.3	2.2	7.3	3.6	18.5	0.3	>15.00	>15.00	>15.00	>15.00	0.00
16-May	10.8	1.9	6.8	3.4	11.6	0.7	>15.00	>15.00	>15.00	>15.00	0.00
17-May	9.1	2.6	6.5	3.9	10.0	1.6	>15.00	>15.00	>15.00	>15.00	0.00
18-May	7.8	4.4	6.0	4.3	10.5	4.3	>15.00	>15.00	>15.00	>15.00	4.00
19-May	12.4	4.9	8.4	5.0	17.5	6.6	>15.00	>15.00	>15.00	>15.00	0.00
20-May	14.4	6.7	9.9	6.4	19.5	8.6	>15.00	>15.00	>15.00	>15.00	0.00
21-May	16.5	4.8	11.2	6.0	19.4	5.9	>15.00	>15.00	>15.00	>15.00	0.00
22-May	13.4	5.1	9.6	6.4	12.7	1.9	>15.00	>15.00	>15.00	>15.00	0.00
23-May	8.4	3.7	7.2	5.0	7.8	-0.8	>15.00	>15.00	>15.00	>15.00	5.00
24-May	10.6	3.3	7.1	4.3	9.9	-1.6	>15.00	>15.00	>15.00	>15.00	7.00
25-May	9.9	3.7	7.0	4.6	8.0	-0.6	0.45	>15.00	0.35	>15.00	4.00
26-May	6.9	2.6	5.3	3.7	8.2	-1.1	0.45	0.48	0.35	0.37	13.00
27-May	9.3	2.3	6.5	3.6	9.4	-0.1	0.46	0.50	0.35	0.37	7.00
28-May	11.7	2.6	7.6	3.9	12.0	1.5	0.45	0.49	0.35	0.36	0.00
29-May	13.1	3.3	8.9	4.6	15.2	1.7	0.45	0.48	0.35	0.35	1.00
30-May	12.0	3.3	8.1	4.9	13.0	1.2	0.44	0.48	0.34	0.35	3.00
31-May	13.0	5.3	8.9	6.0	12.5	2.9	0.44	0.47	0.34	0.35	1.00
01-Jun	15.1	3.7	10.0	5.3	14.5	2.0	0.43	0.47	0.34	0.35	0.00
02-Jun	15.9	4.3	10.6	5.9	15.3	1.3	0.44	0.47	0.34	0.35	0.00
03-Jun	12.8	4.5	9.3	6.7	11.7	-0.2	0.45	0.48	0.35	0.35	0.00
04-Jun	11.1	3.3	7.8	5.1	7.0	-1.1	0.46	0.50	0.35	0.36	0.00
05-Jun	8.2	2.9	6.6	4.6	7.9	-1.7	0.47	0.49	0.35	0.36	0.00
06-Jun	14.6	3.1	9.6	4.6	15.4	2.2	0.45	0.49	0.35	0.36	0.00
07-Jun	12.8	5.6	9.3	6.5	16.2	6.9	0.45	0.48	0.35	0.36	0.00
08-Jun	11.2	6.2	9.1	7.0	13.1	5.6	0.45	0.48	0.35	0.36	0.00
09-Jun	13.8	6.3	9.4	6.9	13.9	4.9	0.45	0.48	0.35	0.36	0.00
10-Jun	17.7	5.5	11.8	6.7	19.6	3.9	0.45	0.48	0.35	0.36	0.00
11-Jun	14.2	8.3	10.9	8.8	15.6	6.3	0.46	0.48	0.35	0.36	0.00
12-Jun	14.4	6.0	10.0	7.7	10.5	0.8	0.45	0.50	0.35	0.36	0.00
13-Jun	11.3	4.8	8.5	6.5	8.3	0.5	0.47	0.51	0.36	0.37	1.00
14-Jun	13.7	4.8	8.8	6.1	10.5	0.6	0.46	0.50	0.36	0.37	0.00
15-Jun	9.8	4.7	7.9	6.0	8.5	1.2	0.48	0.50	0.36	0.37	0.00
16-Jun	12.0	4.3	8.5	5.7	11.3	0.4	0.48	0.51	0.36	0.37	0.00
17-Jun	9.8	4.4	7.6	5.6	5.3	0.4	0.45	0.51	0.35	0.37	8.00
18-Jun	11.4	4.6	8.4	5.7	12.5	1.9	0.45	0.48	0.35	0.37	0.00
19-Jun	14.6	4.9	9.5	6.1	12.6	1.7	0.45	0.48	0.35	0.37	2.00
20-Jun	17.3	5.3	11.6	6.6	17.7	5.3	0.44	0.48	0.35	0.36	0.00
21-Jun	11.9	7.6	9.7	8.3	12.1	5.3	0.44	0.47	0.35	0.36	3.00
22-Jun	12.2	7.6	9.9	8.2	12.2	5.3	0.44	0.46	0.35	0.36	11.00
23-Jun	13.4	8.1	10.5	8.4	11.0	4.9	0.43	0.45	0.34	0.35	4.00
24-Jun	13.3	8.0	10.5	8.5	11.7	4.9	0.43	0.45	0.34	0.35	20.00
25-Jun	13.6	7.4	10.7	8.3	13.7	5.6	0.43	0.45	0.34	0.35	3.00
26-Jun	14.4	7.3	10.5	8.0	14.1	5.7	0.43	0.45	0.34	0.35	24.00
27-Jun	13.7	7.6	10.9	8.2	13.3	4.8	0.43	0.45	0.34	0.35	5.00
28-Jun	15.7	7.1	11.7	8.2	17.0	4.3	0.43	0.46	0.34	0.35	0.00
29-Jun	18.5	7.7	13.4	8.7	20.8	6.0	0.43	0.45	0.34	0.35	0.00
30-Jun	18.4	10.0	13.6	10.2	20.1	8.7	0.43	0.45	0.34	0.35	0.00

Weather Data 1991

	SOIL TEMPERATURE (C)						SOIL MOISTURE (BARS)				
	2.5cm		10.0cm		AIR TEMP (C)		2.5cm		10.0cm		
DATE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	PRECIP (mm)
01-Jul	15.0	9.4	12.1	10.1	15.9	6.6	0.43	0.45	0.34	0.35	1.00
02-Jul	19.4	7.8	14.1	9.2	20.7	5.1	0.43	0.45	0.34	0.35	0.00
03-Jul	20.1	9.8	14.7	10.7	23.7	8.4	0.43	0.45	0.34	0.35	0.00
04-Jul	20.3	10.5	15.2	11.3	22.9	12.7	0.44	0.46	0.35	0.35	0.00
05-Jul	19.8	10.7	15.1	11.6	20.3	10.6	0.44	0.48	0.35	0.35	0.00
06-Jul	15.8	9.7	13.1	11.2	14.8	3.5	0.46	0.48	0.35	0.36	0.00
07-Jul	12.1	8.1	11.3	9.8	9.9	2.1	0.47	0.49	0.35	0.36	1.00
08-Jul	17.3	7.4	13.0	8.9	19.4	3.1	0.46	0.49	0.35	0.37	0.00
09-Jul	18.2	9.0	14.1	10.1	22.3	8.5	0.47	0.54	0.35	0.36	0.00
10-Jul	17.9	9.9	13.8	10.9	21.0	9.4	0.52	0.68	0.35	0.36	0.00
11-Jul	18.0	11.2	14.1	11.5	21.9	10.5	0.62	0.97	0.34	0.36	2.00
12-Jul	17.8	10.4	14.1	11.2	19.1	8.8	0.65	1.75	0.33	0.36	0.00
13-Jul	17.1	11.5	14.1	11.8	18.5	11.9	1.63	6.38	0.30	0.34	0.00
14-Jul	16.2	10.1	13.2	11.5	15.1	6.0	5.18	6.79	0.28	0.31	2.00
15-Jul	17.0	8.5	13.5	10.1	17.5	3.7	3.27	8.68	0.31	0.32	5.00
16-Jul	13.9	8.9	11.7	9.8	14.4	5.3	0.45	8.68	0.31	0.39	10.00
17-Jul	15.6	8.5	12.5	9.7	16.1	5.9	0.45	0.47	0.35	0.36	0.00
18-Jul	15.5	8.9	12.6	10.0	16.2	5.1	0.46	0.49	0.35	0.36	0.00
19-Jul	13.3	8.8	11.6	9.9	14.8	3.7	0.48	0.52	0.35	0.36	0.00
20-Jul	15.4	8.9	12.5	9.7	17.5	4.6	0.50	0.63	0.35	0.37	0.00
21-Jul	13.6	9.0	11.7	10.0	13.8	5.4	0.62	0.73	0.36	0.37	2.00
22-Jul	16.1	8.5	12.7	9.5	18.0	5.1	0.58	0.74	0.36	0.37	0.00
23-Jul	17.5	9.1	13.8	10.1	21.6	5.7	0.73	3.12	0.37	0.38	0.00
24-Jul	18.7	10.3	14.6	11.0	25.3	8.9	3.12	>15.00	0.36	1.12	0.00
25-Jul	19.6	11.9	15.1	12.1	27.4	11.2	>15.00	>15.00	1.13	4.65	2.00
26-Jul	17.6	10.2	14.1	11.3	18.6	7.8	0.64	>15.00	1.49	6.13	19.00
27-Jul	15.4	10.1	12.9	10.7	17.0	7.8	0.50	0.64	0.44	1.48	0.00
28-Jul	15.5	10.1	13.1	10.9	17.2	6.7	0.51	0.55	0.41	0.44	0.00
29-Jul	15.9	9.8	13.1	10.7	18.2	6.8	0.54	0.65	0.43	0.46	0.00
30-Jul	16.2	10.4	13.2	10.9	18.3	6.2	0.64	0.90	0.46	0.58	0.00
31-Jul	15.8	8.8	12.9	10.3	19.8	4.4	0.90	1.99	0.58	1.18	0.00
01-Aug	17.1	9.7	13.6	10.5	21.2	7.1	1.99	12.53	1.18	4.16	0.00
02-Aug	16.2	10.2	13.4	11.1	20.9	10.2	12.59	>15.00	4.16	7.84	0.00
03-Aug	17.6	10.3	14.0	11.1	21.9	7.6	>15.00	>15.00	7.81	12.15	0.00
04-Aug	18.8	11.2	14.7	11.7	24.2	11.3	>15.00	>15.00	11.22	>15.00	0.00
05-Aug	19.4	11.3	15.0	12.0	24.5	11.1	>15.00	>15.00	>15.00	>15.00	0.00
06-Aug	17.4	11.6	14.4	12.2	21.8	9.8	>15.00	>15.00	>15.00	>15.00	0.00
07-Aug	15.7	11.0	13.5	11.9	21.0	7.8	>15.00	>15.00	>15.00	>15.00	3.00
08-Aug	17.8	11.3	14.1	11.8	21.4	9.8	11.25	>15.00	>15.00	>15.00	0.00
09-Aug	18.7	12.4	14.6	12.3	21.4	13.1	13.00	>15.00	>15.00	>15.00	0.00
10-Aug	14.2	11.5	13.2	12.1	15.7	7.7	>15.00	>15.00	>15.00	>15.00	0.00
11-Aug	13.1	10.5	12.1	10.9	12.2	6.7	0.71	>15.00	>15.00	>15.00	16.00
12-Aug	13.7	10.5	12.0	10.8	13.9	6.7	0.53	0.75	0.63	>15.00	1.00
13-Aug	13.5	10.2	11.8	10.5	13.8	7.1	0.45	0.53	0.35	0.62	5.00
14-Aug	13.1	9.7	11.5	10.3	15.1	6.9	0.45	0.48	0.35	0.36	4.00
15-Aug	15.9	10.6	13.1	10.8	18.0	8.6	0.45	0.47	0.35	0.36	0.00
16-Aug	17.5	11.1	14.1	11.3	23.1	10.7	0.45	0.47	0.35	0.36	0.00

Weather Data 1991

	SOIL TEMPERATURE (C)				AIR TEMP (C)		SOIL MOISTURE (BARS)				
	2.5cm		10.0cm				2.5cm		10.0cm		
DATE	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	PRECIP (mm)
17-Aug	18.5	12.4	15.0	12.2	26.1	13.0	0.46	0.51	0.36	0.37	0.00
18-Aug	17.4	12.7	14.7	12.7	25.3	12.6	0.50	0.56	0.37	0.38	0.00
19-Aug	19.1	12.7	15.2	12.7	25.2	12.2	0.55	0.62	0.38	0.41	0.00
20-Aug	18.3	13.2	15.1	13.1	24.2	12.9	0.62	0.86	0.41	0.65	0.00
21-Aug	18.7	12.8	15.2	13.0	23.1	10.9	0.86	1.87	0.65	3.24	0.00
22-Aug	18.4	12.2	15.0	12.6	22.9	10.6	1.87	11.40	3.24	8.41	0.00
23-Aug	18.7	12.0	14.9	12.5	22.8	9.3	11.45	>15.00	8.41	13.24	0.00
24-Aug	17.8	11.7	14.3	12.3	19.2	6.7	>15.00	>15.00	13.00	>15.00	0.00
25-Aug	13.6	9.7	12.7	10.9	13.0	4.9	2.81	>15.00	>15.00	>15.00	6.00
26-Aug	13.7	8.2	11.6	9.7	14.6	2.9	1.40	2.81	13.74	>15.00	0.00
27-Aug	12.6	8.6	10.7	9.5	11.6	4.3	0.63	1.53	8.27	13.74	6.00
28-Aug	11.8	8.9	10.6	9.3	11.8	5.8	0.63	0.65	1.95	8.27	0.00
29-Aug	11.5	8.2	10.1	8.9	10.2	4.5	0.59	0.64	1.12	1.95	0.00
30-Aug	11.0	8.1	9.9	8.6	14.2	4.9	0.58	0.62	0.86	1.12	1.00
31-Aug	12.2	9.6	10.7	9.7	14.6	7.9	0.58	0.60	0.80	0.86	0.00
01-Sep	11.3	8.8	10.1	9.3	10.8	4.9	0.54	0.61	0.74	0.84	4.00
02-Sep	12.4	7.1	10.2	8.2	13.0	2.0	0.52	0.56	0.61	0.74	0.00
03-Sep	11.1	6.3	9.3	7.7	12.5	0.6	0.54	0.58	0.59	0.65	0.00
04-Sep	13.4	6.7	10.5	7.6	17.5	2.6	0.54	0.60	0.57	0.64	0.00
05-Sep	14.4	7.7	11.2	8.4	20.3	5.5	0.59	0.65	0.64	0.81	0.00
06-Sep	15.3	9.0	11.8	9.2	22.2	8.5	0.64	0.75	0.81	1.78	0.00
07-Sep	15.2	9.9	11.9	9.8	19.9	7.9	0.75	0.88	1.78	5.19	0.00
08-Sep	12.4	8.8	10.8	9.5	14.2	4.9	0.87	1.00	5.19	8.51	7.00
09-Sep	10.6	7.0	9.5	8.2	10.2	2.7	0.75	0.87	8.51	9.61	0.00
10-Sep	12.8	6.9	10.3	7.9	16.3	2.0	0.72	0.79	7.75	9.98	0.00
11-Sep	13.1	7.7	10.5	8.5	17.0	6.3	0.73	0.81	7.59	9.41	0.00
12-Sep	14.1	8.0	11.1	8.5	21.0	6.0	0.78	0.90	8.69	10.88	0.00
13-Sep	12.9	9.1	10.6	9.5	16.5	6.3	0.89	1.23	10.83	14.61	0.00
14-Sep	10.1	6.7	9.5	8.0	8.9	0.2	0.99	1.33	13.68	15.56	9.00
15-Sep	11.3	6.3	9.3	7.3	14.7	3.6	0.85	1.00	13.06	15.94	0.00
16-Sep	12.7	7.3	10.1	7.8	18.3	4.2	0.81	0.91	11.22	14.54	0.00
17-Sep	12.5	7.8	10.2	8.8	14.8	6.3	0.83	0.99	10.65	13.43	0.00
18-Sep	12.2	6.8	9.9	7.7	16.9	5.1	0.94	1.08	11.88	14.00	0.00
19-Sep	13.6	8.2	10.7	8.5	21.9	5.7	1.08	1.55	13.00	>15.00	0.00
20-Sep	13.5	8.9	10.8	8.9	19.3	7.4	1.55	4.08	15.87	>15.00	0.00
21-Sep	10.4	6.3	9.6	7.8	9.1	1.9	4.08	>15.00	>15.00	>15.00	0.00
22-Sep	9.3	5.5	8.1	6.8	8.8	-0.7	15.95	>15.00	>15.00	>15.00	0.00
23-Sep	7.5	5.5	7.0	6.4	8.5	2.5	15.22	>15.00	>15.00	>15.00	9.00
24-Sep	11.4	5.9	8.9	6.4	14.4	3.3	2.99	15.22	>15.00	>15.00	0.00
25-Sep	12.5	7.0	9.6	7.3	19.2	5.6	1.91	2.99	>15.00	>15.00	0.00
26-Sep	12.7	7.4	9.9	7.7	21.1	6.2	1.66	2.08	13.94	>15.00	0.00
27-Sep	13.4	7.6	10.3	7.9	22.9	6.9	1.69	2.10	12.48	>15.00	0.00
28-Sep	13.6	8.9	10.7	8.6	22.7	9.7	2.08	2.92	12.77	14.97	0.00
29-Sep	12.1	8.2	10.1	8.8	16.1	5.4	2.92	4.81	14.34	>15.00	0.00
30-Sep	10.7	6.8	9.0	7.6	13.6	4.7	4.81	8.72	>15.00	>15.00	0.00